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PRINCIPAL ARMOR PLATE EXPERIMENTS OF 1872.

Our iron-clad ships of war and their armaments are now matters of general rather than professional interest. To discuss such subjects, however, to any good purpose, it is necessary to be well informed of the principal facts bearing on the question. At the conclusion, then, of a year in which public attention has been so much drawn to these matters, a short review of the principal armor-plate experiments that have recently taken place can hardly fail to be useful. In taking up this task it is proposed to keep in view the object of supplying means of reference to those who have not the time and opportunity to register or make records for themselves, and to this end to add only to the bare facts of the case such deductions as it is presumed would pass unchallenged by any reasonable scientific man. The facts and details, it may be observed, have been taken, except where the reverse is distinctly stated, from careful examination made at the time and place of each experiment.

On June 20th, 1872, the 35-ton gun (the so-called Woolwich Infant) was first tried against armor plates. This trial took place at Shoeburyness under the following circumstances:—

The gun having been bored up from 11.6 in. to 12 in. calibre, was found to be capable of consuming in its bore about 110 lbs. of pebble powder. There appears to be no doubt that better performances might be expected from this gun, were it not for the requirements of naval service, which limit its length, and consequently the charge of powder which it is capable of burning; but of this more hereafter. As it actually came forward for trial, it discharged a projectile of 700 lbs. weight with an initial velocity of 1,300 ft. a second, giving about 220 foot-tons on each inch of circumference of the shot.

This last expression may need a word or two of explanation to non-professional readers, or even professional ones who may not have specially studied this question. It will be readily seen that more force is required to drive a large projectile through a plate than a small one. Therefore if the object is to know the depth to which shot will penetrate, size must enter as an element in the question. Now it has been found that an approximate standard of comparison is furnished by dividing the total energy stored up in a shot by its circumference. The reason of this is not difficult to see. Suppose the shot to act literally as a punch, and to clip a round disc out of the plate, of sufficient size to let the shot enter; it is clear in such a case that work performed is simply that of shearing the plate round the edge of the shot. Thus the energy of the shot will be met by the resistance required to shear the target in this manner in a line which concides with the exact circumference of the shot. No doubt this supposition is not correct, as any one knows who has seen plate-firing. It is, however, sufficiently near the truth to furnish a standard of comparison between shot of various calibres. Thus a 9-in. projectile with a "penetrating figure," as it has been called, of 100 tons—

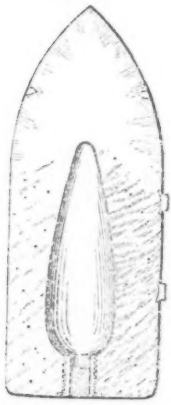
that is, one that exerts 100 tons pressure on each inch of its circumference—is found to enter a plate to about the same depth as a 12-in. projectile with the same penetrating figure, the only difference being that the hole in the latter case will be 12 in. in diameter, and that in the former 9 in. only.

This being clearly understood, it will be seen that the projectile of the 35-ton gun, with an estimated "penetrating figure" of 220, on leaving the muzzle of the piece, possessed enormous punching power as compared with its predecessors, whose figures were the following:—that of the 12-in. gun of 25 tons, 188; the 11-in. of 25 tons, 187; the 10-in. of 18 tons, 166; the 9-in. of 12 tons, 125; the 8-in. of 9 tons, 100; and the 7-in. of 6½ tons, 85. Further, from its increased length and weight, the 700 lbs. shot would be found to lose its power less rapidly than its predecessors as the range increased. This, however, does not concern the experiment now referred to, as the gun was mounted at only 70 yards' distance from the target.

We pass on to the projectiles employed. Palliser shot and shell exist in the service for most of our heavy guns. It has recently been decided, however, to supply only one armor-punching projectile to the larger calibres for the future; this being a shell with thick walls which may be fired empty as shot, or with the bursting charge required to give the explosive action of a shell. Against armor, as most of our readers are no doubt aware, the mere impact of the projectile fires the charge, so that no fuse is necessary. Fig. 1 shows the projectile of the 35-ton gun in section. The head is chilled by being cast in metal; the remainder of the mould being of sand, the body of the projectile cools slowly and is mottled. Thus, while the head has the maximum density, hardness, and crushing strength that can be given it, the body is left with as much tenacity as belongs to mottled iron in its normal condition. The head is what is termed ogival, the curve being struck with a radius of 1½ diameter. It is found to penetrate best when fired as a shot; the action of the bursting charge, taking place before the projectile reaches its full depth, interferes with penetration when the armor is very strong, but when the front plates are not very thick the backing may be shattered to a greater extent from the explosion of a bursting charge.

The target, which had been used to test heavy guns at Shoeburyness most recently, was one known as No. 33. It consisted of the following layers of material: 8 in. iron, 6 in. teak, 5 in. iron, 6 in. teak, and 1½ in. iron skin. This structure had already been pierced by the 11-in. gun with a penetrating figure of 187 foot-tons. It was clear that it would need to be strengthened to test the powers of the 35-ton gun if fired

FIG. 1.



direct at a range of 70 yards. For this purpose a 4-in. plate was fixed on the front of the structure above described, giving a total amount of 18½ in. of iron, and 12 in. of teak. The method of applying the 4-in. plate deserves special notice. It was not laid or fastened in contact with the front plates; but by inserting between it and the target face a framework of 4-in. battens, an air space of about 4 in. was formed. This space greatly disturbed the conditions under which it was generally understood the experiment would take place. On former occasions projectiles have given very exceptional results when fired at plates fixed with an air space between them. The fact appears to be that the shot probably becomes fractured in its passage through the front plate, when the pieces, as long as they are held by the surrounding metal, may drive forward, but when not so held they spread out, falling as "langridge" on anything beyond; if this be not the case the double shock has a strange power of shattering.

It is difficult to arrive at the reason for the front plate having been put on in the manner described. The Director of Naval

Ordnance and others seemed quite unprepared for such an arrangement.

Supposing the target to have been made up in the usual manner, it was very nearly a match for the gun. The No. 33 target unstrengthened may be estimated from former trials as requiring a penetrating figure of about 140 to pierce it. Supposing the front plate to have been increased in thickness by 4 in., about 20 would have to be added for each inch, bringing the total figure up to about 220. The separate plate laid close on the face probably represents something less; but how much it is difficult to say, and the air space greatly complicated the question.

For the first round the projectile was filled with a bursting charge of about 91 lbs. of powder.

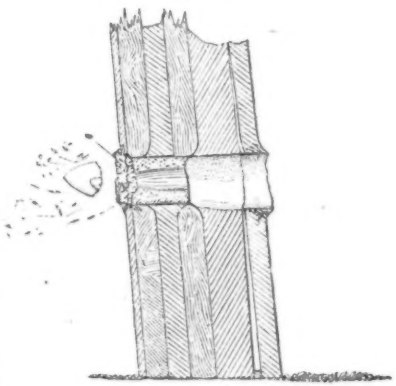
The results were as follows: The head and front portion of the shell were driven through the plates and buried in the backing. The back of the target was bent back slightly and some bolt and rivet heads dislodged, and the battens supporting the front 4-in. plate were blown away, causing that plate to fall back so as to lie nearly in contact with the target proper. In this condition the second round was fired at it, the projectile being fired empty to act as a shot. The result was complete penetration—that is, the projectile got its head and shoulders well through the target, the base breaking away, and the body being left standing like a sort of tube in the rear plate and backing, and showing daylight through the target (*vide* Fig. 2).

The deductions which appear to follow from this experiment are—

1st. That the penetrating power of the gun is probably about what was estimated—viz., 220 tons per inch of shot circumference at the muzzle. It is impossible to speak definitely from such an experiment, but with the 4-in. plate nearly in contact with the target proper, the power necessary to give complete penetration—that is, to force some part of the projectile completely through the skin—can hardly be much less than 200, and it may even exceed that figure by 10 or 20. The second round had certainly a good deal of energy to spare, for it drove the projectile through as far as its shoulders and sent the head on.

2d. The inferiority in effect of the first round was due either to the fact of the air space, or to the employment of the bursting charge, or possibly to the combination of air space and bursting charge. For the 4-in. plate being sufficient to explode the shell, the bursting charge would disperse the fragments where opportunity was given it to do so. The precise effect of these causes is clearly a matter of opinion, and not, therefore, within the province of this article. It was a happy circumstance that the shell so far blew away the battens and threw the front plate against the target proper as to simplify the conditions under which the second round was fired.

FIG. 2.



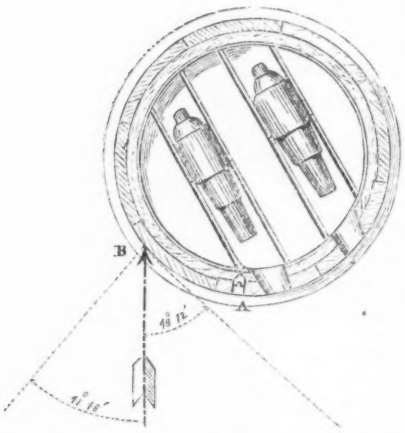
The next important experiment was the trial of the Glatton turret at Portland, on July 5th.

The object of this experiment was to test the liability of the revolving gear to be put out of order by a heavy blow on the armor of the turret, and further, to ascertain whether the turret was liable to be wedged or jammed by the entrance of a projectile close to the junction of the turret and glacis plate. No bursting charge was in either case to be employed. The Hotspur, drawn up at 200 yards' distance, actually fired two rounds at the Glatton turret, not counting one which passed close over the top of the turret, cutting through the iron rails only. The first of these two rounds was intended to strike the turret near the top so as to act on the lower part with the maximum leverage. The strongest part of the turret—that is, one of the 14-in. plates—was selected, so that as heavy a blow as was possible should be given. A 12-in. plate would, in the event of complete penetration, have allowed the shot to pass through without giving the greatest shock

which it was possible the turret might receive if the stronger part were struck.

Fig. 3 shows the arrangement of the armor to a certain extent. The front plates were laid on in two rings or tiers. The upper ring consisted of two 14-in. plates over 15 in. oak backing, and six 12-in. plates over 17 in. of backing, the total thickness of plate and backing being everywhere 29 in., the thick plates being those containing the ports. The lower tier differ-

FIG. 3.



ed from the upper in having but one 14-in. plate—viz., that one breaking joint with the thick plates in the upper tier. Everywhere there was a 1½-in. skin, consisting of two ¾-in. plates; then came vertical girders 5 in. deep, and finally on the inside edges of these a mantlet skin ¼ in. thick, to prevent bolt heads, nuts, etc., from flying into the interior of the turret.

The first shot took effect a few inches lower than was intended, striking the 14-in. plate near its junction with the 12-in. plate below it (*vide* Fig. 4, also at A in horizontal section, Fig. 3).

The following effects were produced:—

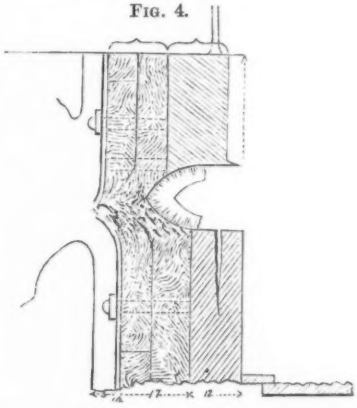
The upper plate was driven bodily about 5½ in., and lifted up so as to open the joint beneath it to a width of 2 in. The lower plate had a laminating crack formed in it, and was squeezed and contorted at its edge. The shot itself penetrated to a depth of about 20 in. A bolt was driven some distance backwards, the point flying off into the interior of the turret. The skin proper was bent back and opened to a width of about 3 in., the wood protruding through it. Lastly, a large sheet of the mantlet skin was torn off, and a number of rivet-heads detached.

Though not quite the blow that was intended, it is evident that the turret received a very heavy contorting shock, nevertheless it revolved without the slightest obstruction.

The second shot was aimed lower, and actually struck close to the junction of glacis and turret. It first impinged on the glacis-plate, and glancing along it entered the base of the turret to a depth of about 15 in. The shot came out easily, being entire from the point to the front ring of studs. The glacis-plate was grooved and cracked through, and the flange-plate at the base of the turret was cut through (*vide* Fig. 5). The turret again worked easily and well, and was really in very good fighting trim, in proof of which it was made to revolve and the guns fired.

It is a question how far the liability to jam might have been more severely tested. The vessel might have had a list given towards the Hotspur, as originally intended, to represent the circumstances of a shot proceeding in a slightly downward direction. Unless the shot, however, had remained with a very large portion projecting, it is hardly likely that the turret could have been jammed. Detached pieces of the glacis-plate, which is only 3½ in. thick,

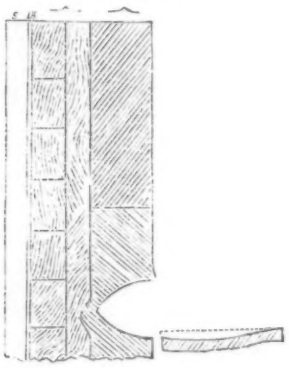
FIG. 4.



could hardly have wedged up the 6 in. space round the turret; besides, the crew would have found access to them from below, without exposing themselves. The Glatton turret, then, admirably stood the

test to which it was exposed. It has been suggested, however, that the revolving gear would be more severely tried by a blow striking more nearly in a tangential direction, so as to tend to produce sudden rotation or to check it suddenly if in motion. The maximum effect in this way must accompany the blow that strikes as near to the tangent as it can without glancing. With the service form of head (viz., the ogival of 1½ calibres radius), the maximum angle with the normal or radial line to the turret is 41 deg. 48 min. The Glatton turret is nearly 31 ft. in diameter; the leverage with which a shot might act, striking as above indicated, is 10 ft. 2.97 in. (*vide* B on Fig. 3). It seems highly improbable that the blow of a shot, acting at the end of an arm of this length, would be likely to start in motion a mass of such weight and so long a radius of gyration as a turret, with its heavy ring of armor. This, however, is a matter open to doubt, and to this, one more suggestion may be added. It appears obvious that to injure the gear of a turret in any way the turret itself must be put in motion. To do this a distributed blow rather than any local destructive effect, is required—in fact, as much of a push and as little of a blow as possible. The heaviest shot proceeding at the slowest velocity is the Rodman, and it would be interesting to try its effect, but how far it would be really useful to do so is a question. The 35-ton gun, at all events, could hardly produce more effect on the turret than the 25-ton gun. Its shot is the same calibre—12 in.—and the only addition of force that would be expended on the turret armor would be that amount required to complete the passage of the 600 lbs. shot through the backing.

FIG. 5.



Sir Joseph Whitworth's shot generally stand up without fracturing on impact, and he has certainly shown that he can obtain penetration at unusually oblique angles. It may be questioned by some whether a well-directed blow from a flat-headed steele Whitworth projectile at the junction of glacis-plate and turret might not temporarily jam and rivet the whole together. In fact, theoretically, a Rodman shot at the submit and a Whitworth projectile at the base, would be the most trying programme that could be devised.

This leads, naturally, to the recent public trial of Sir Joseph Whitworth's breech-loading gun and shot at Southport, on October 8th last.* The gun was only a 9-pounder, and its chief characteristics only affect the question of armor-piercing, as far as they concern the general power of the guns. The experiments, however, deserve notice as the public performance of a feat hitherto known to few except by report and inspection of perforated fragments of plate, etc. This feat is the entrance of a flat-headed projectile into a plate at an angle of 45 deg. The 9-pounder gun, with its enlarged chamber, took a firing charge of 2¾ lbs., with which, at 100 yards' range, it drove a hexagonal steel shell, 13½ in. or 5 calibres in length, through a 3-in. Cammell iron plate, fixed with an inclination of 45 deg. to the horizon. The projectiles are beautiful specimens of steel shells, and, as a rule, they stand up to their work, although on this occasion one shell, which did not completely penetrate, broke up. The shells are made from ingots of steel, cast in the form of hoops, and drawn down to the necessary size under the hydraulic press. They are therefore less costly than might be supposed. Sir J. Whitworth appears to some extent to have adopted ogival-headed shot for direct fire against plates, but he maintains that he cannot get them to penetrate at such oblique angles as the flat-headed ones.

The discussion of experiments such as the foregoing naturally raises the question as to the measure of safety now secured to a vessel by the employment of armor plates. Some writers speak of our iron-clads in

* For description of this gun see "Naval Science" for April, 1872, page 141.

terms calculated to encourage the belief that a vessel on active service would, in all probability, soon fall under the fire of a gun capable of penetrating her armor and rapidly destroying her. A few facts as to the state of the case, then, may prove to be of value.

Let us compare the relative powers of mutual destruction possessed by the original and recently-constructed iron-clad ships.

Had two Warriors engaged one another with their original armament of 68-pounder smooth-bore guns, they would have failed to penetrate each other's side at 200 yards. With guns afterwards placed in them, the Woolwich 7-in., they could pierce each other's armor up to a range of about 1,270 yards, supposing them to act under the most favorable circumstances.

Two Devastations or Thunderers with the 35-ton gun, could pierce each other's armor of 14-in. plates at about 1,200 yards, while two Glattons, carrying 25-ton guns, would have to come within about 220 yards to penetrate 14-in. armor, and 1,560 yards to pierce the 12-in. armor. As a matter of fact, it is probable, from the vessels receiving the shot at an oblique angle to their sides, that they might advance still closer to the muzzles of the guns than has been indicated. It is obvious, then, that while armor is not what it was at the first moment of its adoption, it has not been mastered by the guns at all to the extent generally supposed, two Thunderers having, in fact, rather less power to destroy each other than two Warriors carrying 7-in. guns.

OF TUYERES FOR BLAST FURNACES.

By F. BUTTGENBACH, Neusser Iron Works.

From "Engineering."

Every practical blast-furnace engineer knows the inconvenience, labor, and often seriously disadvantageous consequences which are connected with the removing of a damaged water tuyere. If the mouth of the tuyere has become "ironed," or encrusted with lumps of molten iron or slag—lumps which often assume extraordinary dimensions, thus preventing their passage through the tuyere holes—the latter have often to be widened to such an extent that the regular working of the furnace is interfered with. It further happens, sometimes, that the mouth of the tuyere gets leaky, thus interfering with the production of the furnace before the true reason for it can be ascertained, and the substitution of the new tuyere is then attended with all the above difficulties. It is, therefore, a highly important matter to ascertain, in the choice of tuyeres, what form or construction of tuyere will remove the difficulties above referred to; and it will be generally allowed that if such a tuyere can be procured, the first cost becomes a matter of minor importance, as it will soon be more than covered by the saving of the cost of the interruption in the working of the furnace. For the purpose of obtaining a satisfactory form of tuyere, I have, since 1859, carried out at the Neusser Iron Works a series of experiments with variously constructed water tuyeres. The tuyeres mostly used in England, and made of helical iron tubes, either placed simply in loam, or, as is more usual, surrounded by cast iron, I found to give the least satisfactory results. These heavy and unmanageable lumps cannot resist the contact with the fluid iron and iron-containing slag; they are soon worn off by any contact with the fluid mass of metal, become leaky, and occasion accumulations which become so intimately connected with the moths of the tuyeres that often great portions of the wall of the hearth have to be broken away in order to get them out. Such a tuyere costs at Neuss at least 4 groschen (4.8d.) per pound; if 24 in. long weigh about 250 lbs.; and if burnt away at the mouth it becomes of scarcely any value whatever.

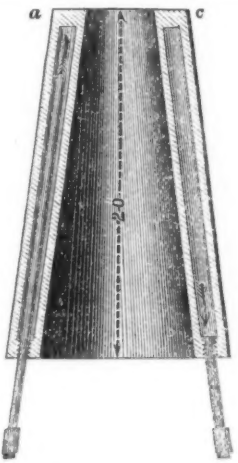
I next tried wrought-iron tuyeres with welded seams. These gave better results, but they also could not withstand the contact with the molten metal, and became united to the latter, though the tuyeres were not so easily damaged as those of the first-mentioned construction.

However, when the tuyeres had to be removed the same difficulties were met with as with those previously described. It is also difficult to ascertain beforehand the perfect soundness of the weld. Some of these tuyeres were often not many days in

the furnace when leaky seams were discovered at the mouth, thus necessitating their being taken out, and this would happen notwithstanding the perfectly satisfactory testing of the tuyeres with a water pressure of from 10 to 12 atmospheres. The best mode of testing such tuyeres consists in filling them with water, and after driving wooden plugs into the inlet and exhaust openings, placing the tuyeres perpendieularly, with the mouth upon a fire, until the wooden plugs are thrown out by the pressure of steam. If the tuyere withstand this test without leaking, the welded seams are then generally trustworthy. Such a tuyere, if burnt away, is useless except for scrap iron. The cost of such tuyeres at Neuss is 9 groschen (10.8d.) per pound, and it is difficult to make them well.

I obtained better, and, in fact, thoroughly good results with bronze tuyeres, and I used them for ten years, without ever again applying the tuyeres mentioned above. The bronze tuyeres form less easily a connection with the fluid metal than the iron ones, and withstand the contact with the molten iron very well. Of course they sometimes get cracked; but in that case they are easily taken out, because the bronze, even if connected with the products of the furnace, may always be removed from them with a small amount of force. We may presume that such a tuyere will sustain perhaps ten times the exposure to contact with metal and fluid slag that would be endured by an iron tuyere. I use tuyeres of the pattern shown in the annexed sketch, and have found it the best after many experiments. If made too long the fire is allowed without much hesitation to extend, and the walls of the hearth suffer; if kept short, say 20 in., it becomes necessary with the increasing action of the fire, to renew the ramming in, and the walls of the furnace are preserved. These tuyeres are not easily damaged if well made, and if the precaution is taken to conduct the current of water (supplied through a $\frac{3}{4}$-in. pipe with at least a pressure of 30 ft. to 40 ft., and more if possible) directly to the front of the tuyere, in order to prevent incrustation, though that end is not entirely obtained even by this arrangement. Such a tuyere has to be removed every six months, in order to get the incrustation out either by means of hammering or by drying the tuyere, and making it slightly red hot at the mouth, in which state cold water is poured into it, when the incrustation becomes converted to dust and is washed away by the water; the tuyere may also be boiled with half-diluted hydrochloric acid.

The water is introduced through $\frac{3}{4}$-in. wrought-iron tubes (gas pipes) screwed into the bottom of the tuyere, as shown in the annexed sketch, which represents a fastening that I consider to be the best.



Besides the advantages mentioned above, the bronze tuyeres are more durable, are more easily manageable, and are more uniformly circular than the iron tuyeres, which latter property is always an advantage for the furnace. Moreover, if more expensive in their primary application, they are, nevertheless, much cheaper in their use than the other tuyeres, as the founder will always accept the old metal in lieu of part payment, and I get my old tuyeres recast at 6 groschen (7.2d.) per lb., the new ones costing 17 groschen (20.4d. per lb.).

The bronze tuyeres are therefore certainly the cheapest in their application, but it appears to be no easy matter to have them cast, as it is not every brassfounder who can do it satisfactorily, success depending much upon the selection of the metal and the skill of the founder; in fact the casting of tuyeres is an art, like the casting of bells. I have found that intelligent brassfounders could not succeed, and even large establishments, with all their resources, have tried in vain to obtain satisfactory results. The only useful bronze tuyeres I can obtain are those from a firm at Dusseldorf, Rhenish

Prussia, who have paid special attention to their production.

But even the bronze tuyeres were not perfect; they often became cracked in a manner quite inexplicable, and if they came into contact with the bed of metal from below, would tear or melt. A few years ago my attention was called to the so-called phosphor-bronze of Montifiore-Levy, and everything said about it in private and public reports, and the results obtained from the trials with this metal for artillery purposes, about which a great deal has also been published in England, convinced me that the properties of this metal must offer the same advantages for tuyeres as for guns. It appeared, in fact, to offer greatly increased toughness and density, and, therefore, great resistance against change of temperature and the influence of molten masses. I ordered, consequently, several tuyeres of this metal (according to exactly the same pattern as that for the ordinary bronze tuyeres) of the chief house for this metal at Liege. The matter was taken up there with interest, but no satisfactory result could be obtained, unexpected difficulties being met with, and it being again proved that it is not everybody's business to cast tuyeres. I ordered, therefore, a sufficient quantity of valuable metal, and forwarded it to the firm in Dusseldorf already mentioned, where some excellent tuyeres were cast from it. These tuyeres were soon taken into use, and have given me the fullest satisfaction; they have the advantage of being more tough than the tuyeres of ordinary bronze, and in cases where other tuyeres would certainly have burst, they sustained the shock without any damage being done to them. I ascertained further that this metal does not take up so readily or so firmly the incrustations produced by the contact with the water, and what is of great importance, the oxidation of phosphor-bronze is much more slow than that of the ordinary bronze. A tuyere of the latter metal when used for one or two years, shows at the mouth for a length of 5 in. or 6 in. a green oxidation; it gets rough and cannot be made bright without the use of files; it is thus evident that such a tuyere will more easily take up lumps of the molten products of the furnace than a new and smooth tuyere. The older, therefore, a tuyere of ordinary bronze, the sooner will it be damaged in case of any accident. It is further almost impossible to find always the correct time of cleaning the tuyeres of the inner incrustation; it is forgotten or neglected, and is thus amongst a hundred cases fifty times the cause of a loss. These disadvantages are removed by the properties of the phosphor-bronze, and I have found after a year's use that a tuyere of phosphor-bronze when wiped with a piece of rag appears quite smooth, and has a bright metallic surface, and that it had remained entirely without incrustation. The extra preliminary expense for phosphor-bronze appears almost insignificant in view of the advantages mentioned above, and the expense of recasting this metal being the same as for ordinary bronze, the higher value is in the metal itself.

I am convinced that an ironmaster once using tuyeres of phosphor-bronze will at once find out the advantages of this metal, and will never again apply other tuyeres. Every blast furnace engineer knows that the trouble of taking out one tuyere produces often more expense than the cost of all the tuyeres together of one furnace. If these eventualities can be reduced only one-fifth, the extra first cost cannot be considered any longer. Complete security will never be attained, but I am convinced that the application of the phosphor-bronze for tuyeres is already an important step towards perfection.

THE DEVASTATION.

From "the Engineer."

The Devastation went to sea for a six hours' continuous steaming trial on Tuesday; but it is questionable if the information obtained was worth the cost of the pay of one of the ninety stokers employed on board. It has long been known that the Devastation will float in still water with all her coals, armament, and stores on board; and, as far as figures can prove anything, it is admitted as probably true that she will not capsize unless she is heeled over to a very considerable angle, say 53 deg. And no one regards the continuous working of marine engines for six hours as a very severe test of their

strength and general excellence. The trial trip of Tuesday produced no result calculated to unsettle such articles of faith as these. The Devastation is an experimental vessel in the fullest sense of the word. Nothing is known with certainty as to how she will behave in a seaway. It was hoped that she might have encountered a little rough water in the course of her six hours' run in the Channel on Tuesday, but the weather was, as usual, disappointing. There was no wind and no sea, and the so-called trial trip resolved itself into a little marine excursion for the delectation of the large numbers of officers and visitors on board. Common sense would have indicated the propriety of waiting for a wind before attempting to conduct an experiment to the proper performance of which a moderate gale was essential; but is "red tape" a prominent attribute of Government officials at Whitehall, and as it was stated that the ship would go to sea on Tuesday, she went. The chances are that if it had really blown a gale, she would have stopped in harbor. The water being as smooth as the traditionary mill-pond, the great nondescript craft did just what every one knew she would do. She steamed at the average speed of about 13½ knots for six hours, and then she came back to Spithead; about 50 tons of the best coal having been expended in proving nothing of much value. Only one fact, indeed, of any importance came out during the trial, which is that the condensers are so far defective in some respect not explained, that a wretched vacuum was obtained. The gauge never stood higher than 24½ in., and that only during a short time. The average vacuum was rather under than over 24 in. Now, the barometer stood on Tuesday at about 29½ in., so that the back pressure amounted to 5½ in., or about 2½ lbs., corresponding to a temperature in the condenser of about 134 deg. The temperature of the sea was probably under 50 deg., more nearly 45 deg., and a vacuum of 26 in. should therefore have been easily obtained. The chances are that the circulating pumps do not supply water enough; and some modification will probably be introduced to get over this difficulty. On the other hand, as the engines worked nearly, if not quite, to their maximum power, the test was hardly fair; at least, it it is possible that with a less volume of steam passing through the cylinders a bet ter vacuum may be had. If the action of the condensers was not quite what it ought to be, that of the boilers and engines was all that could be desired. The former supplied an abundance of steam at about 27 lbs. pressure, while the engines made from 73 to 74.86 revolutions without a trace of heating, and without giving the smallest trouble to the engineers in charge. The indicated power was, for each of the twelve half hours of the trial, 5700, 5648, 5699, 5604, 5518, 5803, 5754, 5378, 5592, 5500, 5670, and 5385. There were 1200 tons of coal in the bunkers, and the draught of the ship was 26 ft. 6 in. aft and 26 ft. forward, or a little in excess of her designed load line. The consumption of fuel was 2.896 lbs. per horse per hour. The ventilation of the boiler and engine-room was very defective, and the heat insufferable. This was no doubt due, in some measure, to the calmness of the day. We fancy Mr. Prideaux could suggest an improvement, especially in the matter of fire-doors such as those he fitted to the Republic, and which we have already noticed in our pages.

The Devastation, when at full speed, carries an enormous bow wave. This rises to such a height that the water washes over the whole deck forward, and it is a very grave question how far it will affect her powers of steaming against a head sea. About 11.30 A. M. on Tuesday the ship encountered a slight ground swell, which caused her to pitch and 'scend about 3 ft. Before this she had taken little or no water on her deck forward, but the motion, small as it was, sufficed to send green seas on board; on a small scale, it is true, but very serious as evidence of what may be expected in a gale. Even though the Devastation proves herself a good sea boat—and we are confident she will not, except in a comparative sense—this bow wave is extremely objectionable. We know that it is urged by the advocates of ram and spoon-bill bows that the water is taken up once for all, so to speak, and carried on the bow. We can assure our readers, as the result of a careful personal investigation, that this is not true. The water is continually lifted by ram-bowed ships, and falls off in a cataract at each side, and this is especially the case with the Devastation. We suppose all those who were on board on Tuesday will agree with us in asserting that there is no other ship in existence which creates such a turmoil in the water—a mountain wave ahead continually tumbling over in a

mighty cataract; two wallowing rolls of sea meeting behind in a species of double-wake, thrashed into foam by the ship's great screws. Such is the picture presented by the progress of the Devastation at 13½ knots in a smooth sea. To deny that an enormous amount of power is wasted by the bow wave, appears to us to be sheer folly. Thousands of tons of water are lifted hour by hour to a height of from 5 ft. to 9 ft., only to fall down again. The mere dead hydrostatic pressure brought to bear by the bow wave must in the case of the Devastation amount to a resistance of from 2 lbs. to 3 lbs. per square inch of section. It may be urged that much of this is balanced by the falling in of the water under her counter and stern; but this, from the nature of the case, is impossible, and we are forced to the conclusion that the power of the Devastation's fine engines is wasted in large proportion in doing work better left undone.

It is not probable that any useful test of the qualities of the ship can now take place until autumn; and it has already been suggested that she is too valuable a ship to be tested at all at sea. Nothing would surprise us less than to find that a rumor already in circulation, to the effect that the ship will be put into the steam reserve and undergo no further trials, has a certain basis of foundation in fact. That an attempt will be made to effect this object we believe is not improbable. The ship will be tested as far as the working of her turrets and guns is concerned, and the public will be led to think that she is really being experimented with. Let us hope that those governing naval authorities who love progress—and they are not few—will insist on the ship being utilized to the fullest reasonable extent, as a means of supplying us with information. Great issues depend on the success or failure of the Devastation as a sea-going ship; and even if she foundered at sea, her officers and crew being saved, the loss would be infinitely less than that which may be incurred by perpetuating a type of vessel which may prove useless when most wanted, and in which it is impossible to place any confidence other than that springing from ignorance of her powers.

MEMOIR ON THE EXPERIMENTAL STUDY OF WAVES.

By M. L. E. BERTIN, Naval Architect.

From "Iron."

In discussing by mathematical analysis the equations which express the fundamental laws of the motion of liquids, we obtain for infinitely deep water, and again for the case of water of considerable depth, exact equations in the first case, approximate in the second. All the waves which satisfy these equations can exist in this sense,—that the existence of none of them contradicts the physical laws relating to compressibility and to the hydrostatic equilibrium of fluids; but in order that these waves may really be met with, it is further necessary that there should have been a cause capable of producing them; and as the theory does not take account of the actual formation of waves—that is to say, the action of the wind on the water—it remains to determine by observation what are, among the waves physically possible, those which the wind is capable of raising. Thus, all the *data* that we can desire to have upon waves are determined by theory as functions of L and h;* but, on the one hand, the length remains completely arbitrary, and on the other, the height for a given length—or, in other words, the inclination—is only subject to the condition, $\frac{\pi h}{L} < 1$, due to the impenetrability of matter. Experiment on this point, which must necessarily precede the theory, can only acquaint us with the extreme limits of length and of inclination. It is certainly difficult to assign extreme limits to phenomena as variable as those of the sea.

No observer can assume that he has met with the largest or the highest of all possible waves; nevertheless, by comparing a considerable number of observations, made with care, we must meet some which come very near to the maximum of which we are in search.

* L is the half length or horizontal distance from crest to hollow; h is the half height, or radius of the circle described by the particles of water at the surface of the wave.

The theoretical equation expressing the relation between the period and the speed is

$$T = \frac{\pi}{g} U \quad . \quad . \quad . \quad (1.)$$

In the existing state of our knowledge, we may take 24 sec. as the extreme limit of the period, and 450 metres as the extreme limit of the half-lengths. The height is the element to which, at first sight, most interest seems to attach, and that upon which, in the absence of measurement, a simple guess is the most easily risked.

Waves of more than 4 metres of half height are certainly very far from common. Those of 6 metres are so rare that it is not every sailor who meets them in the course of his career; and we are certain, in adopting 16 metres as the maximum limit of height, to have got beyond all the observed values. I only speak of waves in the open sea, and of those belonging to a single swell. An isolated rock 25 or 30 metres high may be covered by a breaking sea. Waves belonging to different systems of swell may ride one over the other, giving rise to topping seas without speed and with a short period, or to any other irregular and exceptional agitation, such as may be imagined, for instance, to take place at the centre of a cyclone.

A knowledge of the usual dimensions and mean lengths of waves presents even more interest from the navigator's point of view than that of the greatest dimensions. The mean period of the waves in any sea indicates the duration of rolling the most unfavorable that can be given to vessels. This principle is especially true for ships of war, which require to have their best qualities developed in ordinary weather, and in time of battle, and which ought then to be able to use their artillery conveniently under the greatest number of possible conditions of sailing. Shipbuilders have thus great need to be acquainted with the mean period of the waves. The following extract presents the best datum that can be quoted as to the mean period of waves :—

Where met with.	Mean half period.
Atlantic—the trades	2.90 seconds.
South Atlantic, (region of the westerly winds)	4.75 "
Indian Ocean, south (region of the easterly winds)	3.80 "
Indian Ocean—trade winds	3.80 "
China seas	3.45 "
West Pacific	4.10 "

In order to differentiate the waves one from another, it will be necessary to select as the characteristic element the period, not only because it is the most interesting element as regards the construction of ships, but also because it is really the characteristic element, since, as the swell calms down, the length remains constant, while the height diminishes. The natural division of the sea in respect of roughness seems to present a very close analogy to the division in respect of the probable winds by which navigation under sail is governed; for the principal winds on the surface of the globe differ from one another in force as well as in direction. Nevertheless, as the motion of waves is governed by secondary influences, which are still not without importance, such a geographical configuration, depth of water, frequency of squalls, and so forth—the geography of the sea in respect of roughness can only be obtained by observations specially directed to that purpose.

While waiting for a natural division, the result of experience, it is important, with a view to classifying our observations, to sketch out a provisional division of the ocean with the help of the charts which indicate the leading winds.

We find divisions which present themselves almost of their own accord, in the zones separated by parallels of latitude which mark out in both hemispheres the regions of westerly winds, the trades, and the intermediate and irregular winds. These zones do not exactly correspond with the two hemispheres, and in either hemisphere they vary a little according to the season.

The study of the leading divisions should not permit us to neglect those of local subdivisions, which it might be convenient to mark out in order to obtain a detailed knowledge of the seas which are of especial interest, whether on account of the maritime roads which cross them, or of their calmness or roughness presenting any special characteristics. All the European Seas should be reserved for special study. In the equatorial region, it will be necessary to distinguish with care the portions which are really calm. The zones near the shores should be the subject of distinct studies, including the observations of the currents, and also the sharpness of the waves, which would exhibit the influence of the bottom, and of the neighborhood of

the coast. Both of these deserve a particular study. Local sub-divisions, which are very important for navigation, and of which the study would involve sending several steamships out of their direct course, offer very little interest to the shipbuilder, and what the latter wants are chiefly the average data for large divisions. The geographical division of waves, that is to say, an account of the maximum and mean dimensions of waves for the various regions of the globe, is not sufficient for the study of the laws of the phenomena.

For a full comprehension of the observed facts, and a consequent discussion of the results obtained, we must add to this geographical study what we may call a mechanical study of the swell of the sea, that is to say, the observation of the wind which produces the waves and the relation which exists between the diminution of the waves and the speed of the wind which has raised them. The study of the mean winds prevailing in each region has already been carried to a high degree of perfection. It would, in strictness, be sufficient to add to it the study of the waves to have very nearly both terms of the comparison which we have to make. But it will be much more interesting to carry on the two observations simultaneously, and to be able to tabulate opposite each breeze the swell which corresponds to it.

A relation has been sought for between the height of the waves and the speed of the wind, but no such relation has been discovered. The table prepared on the supposition that the cube of the height of the waves is proportional to the square of the speed of the wind, can only be accepted as a provisional theory, subject to future experimental verification. The question thus remains unsolved. The length and height of waves are both quantities depending upon the wind. Let us, for instance, consider in an infinitely extended sea that the swell has reached a permanent and invariable condition. The work due to gravity and to the inertia of the liquid has disappeared. The resistance of the molecular forces is equal to the actual work of the wind. The molecular work only depends upon L and h. The action of the wind depends upon the same data, and on the relative speed of the wind V—U with reference to the swell. There thus exists a necessary relation between these three elements, and consequently, among the various swells which can satisfy it, that one will have the greatest tendency to be formed whose speed U differs the least from V, and the molecular work to produce which will consequently be the least. All the elements will thus naturally be determined as functions of the speed, a thing which we might have regarded as self-evident. Observations, which it would not be difficult to obtain, would acquaint us with the value of the terms of the preceding equation, and would thus give us a sort of experimental analysis of the formation of waves. The work of resistance due to weight and to inertia for a known increase in the size of the waves is, in fact, easy enough to calculate. The study of the time necessary for each swell to retain its fixed and permanent condition under the action of the wind which produces it, is also very interesting. Pretty nearly constant, both in intensity and in direction, all interest in the connection between the wind and the swell would disappear. The length of waves and their inclination for a given length would be just as irregular as meteorological variations. If the waves soon reach their regular conditions—a fact which seems to be pretty well established—one is necessarily driven to adopt the law that for each length of waves there is a certain height which is most commonly met with, and which cannot be exceeded. The general law for progressive waves— $\pi \frac{h}{L} <$ is replaced for sea waves in particular by a certain condition—$\pi \frac{h}{L} < F(L)$; a formula which depends not upon properties of fluids, but upon the action of wind upon water, and which can only be determined by observation. The relation between the maximum steepness and the length of swell is very important to be known for the purposes of naval architecture, since from theory it appears to be less dangerous for ships to have their rolling isochronous with certain swells, than with certain others, which are steeper than the first. Thus in an investigation which might be supposed devoted to waves alone, a consequence is immediately applicable to ship-building.

The greatest inclinations for various lengths of waves are the following:—In waves, several metres in length, the ratio of h to L reached 0.16; on waves of 52 and 50 metres half-length this ratio is again between 0.122 and 0.127, while for waves

whose half-length is 75 metres this ratio falls to 0.065. For waves of 85 metres of half-length the ratio is only 0.052. Again, for waves whose half-length reaches the extreme of 450 metres, the ratio of h to L will only be about 0.02.

On the other hand, it appears probable that the law according to which the ratio of h to L diminishes as L increases, which appears from the preceding numbers, is too high.

In studying rolling with reference to the mass of known observations, I consider three different values of the maximum steepness of waves, corresponding to the ratios 0.05, 0.10, and 0.15 of the height to the length. I assume that the first is never reached in the longest swell; but that it is met with on swells of a period from 6 to 7 sec. isochronous with the rolling of large vessels. I assume that the second is capable of existing on swells long enough to be taken into account in the study of rolling. I assume that the third can only be met with in exceptional short and sharp seas, and may be regarded as an extreme limit. The verification of the equation which connects the lengths and the periods deserves to be continued by observers, in order to ascertain the degree of its exactness. As the theory of the swell takes no account of the cause which produces it, it is possible that the theoretical speed U might be rather less than the real speed of propagation. This would be shown by a diminution of the period T: the observed lengths L would be greater than the theoretical lengths, $L^1 = \frac{g T^2}{\pi}$.

In the Table of diminution of waves, classified according to the intensity of the wind, the values of L always exceed those of L^1, and the mean difference is about $\frac{1}{7}$ of L. The result is given in the following Table:

Measures in Metres.

	Speed of wind.	Half height mean h.	Half Length.		Ratio $\frac{L - L^1}{L}$
			Observed, L.	Theoretical $L^1 = \frac{g T^2}{\pi}$	
Very heavy sea	28.5	3.88	74	58	0.22
Heavy sea	20.0	2.52	53	45	0.15
Rough sea	13.4	1.77	38	30	0.27
Heavy swell..	9.2	2.05	60	59	0.01
Swell..... ...	5.9	1.20	39	33	0.15
Calm	5.7	0.80	31	25	0.19
Mean....	....	....	....	....	0.165

It is well to remark with reference to this table that the verification of the theoretical law is much better for the three last sorts of swell, which are steady swells in process of extinction, than for the first three, which were probably accompanied by the wind corresponding to them.

The period T may be obtained by the help of the double "oscillographe," intended for the simultaneous measurement of waves and of rolling, which records at every moment the inclination of the waves projected on the transverse section of the ship. The use of this instrument of exact observation, even if it became general, would not take away from the interest of any of the old modes of observation, for this double "oscillographe" can only give good indications for the case of very heavy regular swells taking the ship nearly in a transverse direction. The record produced by this instrument requires, moreover, to be aided by direct observation. As soon as the sea presents a roughness capable of producing observable rolls, it is possible to count the number of waves which pass in a given time, with the help, if needs be, of a float towed at the end of a long line, so that its rise and fall can be observed with reference to the horizon without this being confused by the motion of the vessel.

The period T thus observed must be subject to a correction, in order to take account of the speed of the ship. Thus: Let T be the actual half period; L, the half length; U, the actual speed; U_1, the speed relatively to the ship; all unknown quantities. Farther: Let V be the speed of the ship, and a the angle between the way the ship points and the direction of the swell, or between the directions in which V and U are measured. These quantities, as well as T, being known, we shall have—

$$U = U_1 + V \cos a$$

$$U = \frac{L}{T}, \quad U_1 = \frac{L}{T_1}, \quad L = \frac{g T^2}{\pi},$$

which gives after substituting and reducing

$$T^2 - T T_1 + \frac{\pi}{g} V T^1 \cos a = 0,$$

or, $$T = \frac{T^1}{2} + \sqrt{\frac{T_1^2}{4} - \frac{\pi}{g} V T^1 \cos a}.$$

The + sign being taken when $a < 90°$, and the − sign when $a > 90°$: the speed N is to be taken in metres per second.*

* That is to say, supposing g to be given in metres per second, as 9.8088. If the English measure of gravity, 32.2 is to be used, the only change needed in the formula is to reckon the speed in feet per second—*Translator.*

To this measure of the period it is always easy to add the observation of the height as soon as the waves become high enough to cover the horizon with the ship in the hollow. The observation might be made either through an opening in the bulwarks, or by means of the ratlines. The waves are then completely recorded. If we further wish to add to these observations those of the length and speed, in order to verify our formulæ, we must tow a float in such a manner as to give us an external base of known length, and we must measure either the length of line which is necessary in order that the ship and float may both be on two neighboring crests, or the time which is necessary for a wave crest to pass along a known length of line. When two ships are sailing in company, they give one another a very accurate base for an exact measurement of the length and speed, and even of the height of the waves.

A EUPHRATES RAILWAY.

From "the Building News."

It is not in these columns that the questions of policy and finance connected with the proposal of a new route to India, by way of the Euphrates or the Dead Sea, need be discussed. The only fact relating to these questions which ought to be premised are, that the Suez Canal is entirely beyond our control, could at any crisis be closed against us, and is made the means of laying exorbitant taxes upon our communications and commerce. These circumstances stated, the physical problems alone remain. To no purpose do we deprecate the passion for rapidity now prevalent; it is a characteristic of the age, and every nation outside the torpid circle of Asia must take part in the race; even China and Japan are awakening to the necessity of steam. Whatever is to be done must be done quickly; it is a matter of miles and hours; time is power in our swiftly-whirling days—in trade, in war, in the spread of news, in society itself. We can no more put up with the heavy wading of Dutch keels through the seas, or the creaking waggons of a century ago, than with packsaddles, bridle-paths, and voyages round the Cape. Railways, ship-canals, continents to be channelled across, the globe to be bound in bands of electric wire, the body of the sea itself to be tunnelled—such are the aspirations and tendencies of our age. But England has a peculiar interest in the subject. One half of her empire—and the most important half—lies east of the Isthmus of Suez, and the other west. A waterway has been opened; but it is not English property. Rival projects, therefore, have been for many years on foot, and the principal is that of a Euphrates railway through Syria and Mesopotamia to the Persian Gulf. Strictly speaking, those which we call overland routes are misdescribed, there being no such possibility until the British Channel is either bridged or tunnelled, and until the breadth of waves still separating Europe from Asia has been spanned. Yet an immense space might nevertheless be covered by a railway, whether its starting point be at Alexandretta, in the Mediterranean, which has a good anchorage, though a bad climate, and opens upon an impracticable mountain country, or Suedia, at the outlet of the Orontes, leading into an almost level valley through the Lebanon, into the very heart of the region, and presenting no mechanical difficulties; but it may as well at once be stated that, however easily the Euphrates may be reached, the river itself promises few facilities to modern navigation. It is devious, of unequal width and depth, crowded with natural dangers, liable to sudden and irregular winds, and obstructed at once by rapids, leaping over ledges of rock, and by massive stone dams, of ancient build, which alone keep the current on its course. That it can be navigated from the town of Bir to the sea has been demonstrated; but that its navigation would answer any useful purpose as a connection between England and her Indian dominions may be more than doubted. Small war-steamers, light gunboats, and native craft of immemorial fashion, can travel up and down, though at a slow pace; but even for these the two great streams of Mesopotamia have in wet seasons a habit of flooding their banks, and recreating those great Chaldean swamps celebrated in history. Let us, however, glance at the plans as severally laid down. The distance from London to Kurrachee, in India, by the shortest available route, must be taken at nearly 5,000 miles, and the briefest possible time

for accomplishing the journey at not far from twenty days, unless we imagine many facilities to have been created which hitherto have not even been projected—as, for example, a railway direct through Central Europe to Vienna, with a prolongation to Constantinople or a port in the Archipelago; works insuring an equable flow of the river at all times of the year; navigation without change of vessels, and so forth; but, at the least, we should gain thirteen days upon the Suez route—a matter of great importance to both divisions of the Empire. With reference to the objection that the territories thus traversed are among the poorest in the world, it is founded upon an entire misconception: the people may not be industrious, but the natural riches of those valleys, if developed, might again support the magnificence of Nineveh and Babylon. Nor is it less incorrect to affirm that the inhabitants, miscalled Bedouins, normally live by plunder. They are perpetually fighting, it is true; still, they carry on an extensive commerce; and the migratory hordes are the most profitable customers of the sedentary tribes, which cultivate the soil, trade at the stores of foreign merchants, employ themselves in the manufacture of cotton and wool, and would doubtless be only too glad to become protectors, rather than destroyers, of a railway, if ever constructed. It will be seen that we are suggesting the arguments on either side, without any deliberate judgment on their cogency. However, if practicable, there can be no question of the superiority of this route: it traverses the peninsular triangle of Arabia across its base, from water to water, instead of passing along its two sides. No difficulty now attaches to the overcoming the monsoons, as was the case in the days of canvas power: it leads, instead of the barren sea, through lands capable of producing, and which have produced, cotton, sugar, silk, and tobacco—the finest in the world—in endless abundance. There could be no limit, except in point of demand, to its yield of corn, or of wool, or of valuable dyes. Still, all these considerations must give way unless it be proved either that the Euphrates is sufficiently navigable to support a great commerce between Europe and Asia, or that a railway can be substituted for the water-carriage, parallel with its flow. The most daring plan is that of a line commencing at Calais, continued to Vienna, carried on to the verge of Eastern Europe, then over the Bosphorus, prolonged by way of Trebizond to the Persian Gulf, following its shores, lengthening over the lowlands of the Beloochistan coast, pursuing its course to Kurrachee, and ultimately traversing the peninsula of Gujerat to Bombay. Any geographer could point out, and any engineer well understand, the stupendous engineering difficulties to be surmounted, although all down the Valley of the Euphrates the work might be as smooth as is conceivable, for, on the approach to India, the character of the country changes—the rivers are broad, deep, and changeable—cuttings and tunnels of formidable proportions would become necessary, and the sides of prodigious rocky hills overhanging the sea would have to be scarped for miles. It is to be feared that the estimates drawn up by the authors of these schemes often resemble the calculations of the enthusiasts who are so apt to convince themselves that it would be the easiest thing conceivable to pay off the National Debt. Another idea is that of opening a communication between the Mediterranean and the Dead Sea by means of a canal. Nature having already performed an important part of the work in a stupendous cutting, more than two hundred miles in length, and separated from a sea at either end by a barrier apparently slight at the north, namely, the alluvial plain of Esdraelon, furrowed deeply by the brook Kishon, which might be cut through at a moderate expense, the excavation necessary being no more than twenty-five miles in length, through comparatively soft ground. At the other extremity the distance would not be greater, while the work would be as easy, provided that a certain hypothesis of modern geographers, by no means as yet established, be confirmed, of a dried-up strait. However, assuming all that the projectors fondly hope to be facts, it is forgotten, perhaps, that two thousand miles of Turkish territory would be submerged—though it is of no great value; and that the City of Tiberias must be drowned, though this is little better than a group of filthy mud-huts, or temporary tents upon which not much sentimentality need be expended. The one truth which seems to stand out strongly amidst these varying suggestions is that, sooner or later, a second avenue of approach to our Indian Empire will become essential and will be constructed; the questions being whether it shall be a composite line of canal, rail, river, and sea; or

whether, fearlessly grappling with all the obstacles, our capitalists and engineers will undertake to open the entire route by land, from the shores of the British Channel to the frontiers of Sindh. As to the possibility of the latter project, it is not a question in doubt; the simple problem is how to compass the one supreme difficulty of all modern enterprise, resting on Imperial guarantees and joint-stock speculation,—the cost; but even here exaggerated apprehensions might arise. True, the inhabitants of that region can no longer be compelled to labor for the merest pittance of corn and salt, though M. de Lesseps found the task of persuasion somewhat facile; but labor, in those territories, notwithstanding whatever may be said concerning the sparsity of their population, is marvellously cheap; such labor, we mean, of course, as digging and barrowing away the rubbish. At all events, we are not bound to renounce the scheme as utterly impracticable until a larger knowledge of facts appears to render imperative that which, at present, might be an unjustifiable conclusion.

ON A NEW HYDRAULIC STEARING GEAR.*

From "Iron."

Assuming that the right place of the steering wheel is amidships, and, in large steamships, upon the bridge, the ordinary mode of connection with the rudder, by means of rods or chains, is defective; these connections foul and break, and, in heavy weather, they cannot readily be cleared or repaired. But there is another, and a very important defect in this mode of connection —the loss of power by friction, and by the amount of slack to be taken in. With the ordinary chain and sheave-block gear it takes two men in a ship of, say 1200 tons, to put the helm hard over by six turns of the wheel; but it takes ten or twelve turns of the wheel and more manual power to put the helm as hard over if the wheel is placed amidships. Hydraulics have not been resorted to, from an erroneous idea of creating power, but have been adopted as a convenient method of transmitting a great pressure to any distance, with very little friction, or wear and tear of mechanical connections. Motive force is communicated by the helmsman in the ordinary way, but the action is direct, devoid of friction, and quite noiseless. It is obvious that we recognize the necessity for improvement in steering gear, as we have now several steamships fitted with steam-steering apparatus, and a few fitted with hydraulic apparatus for the same purpose.

In my new steering apparatus a few turns of the wheel are sufficient to put the helm hard over, the power being communicated from the wheel to the tiller by means of water in pipes (a non-freezing fluid is used in high latitudes). Two columns of water are brought to bear, by means of pistons, cross-heads, and pipes, upon the tiller. These columns of water do not communicate; the power being communicated from one to the other, by the cross-heads, in such manner that, when there is a pressure upon one column, there is a corresponding relaxation upon the other. The piston or ram, common to both the cylinders, abaft the wheel, is worked forward or aft by the action of the screw-thread on the axis of the wheel upon the cross-head, which is tapped to it. From each cylinder pipes lead aft to two other cylinders placed at right angles to the line of the keel. The pistons or rams of these cylinders meet in a slot in the tiller; the solid guide-bed grooved for the pivoted block, to which the pistons are connected, insuring direct and smooth action.

There is no vacuum; the tiller being amidships, the cylinders and pipes are quite full of fluid; pressure then exerted by forward piston on one column of water, and so on, across the tiller to the other column, forces the water out of one cylinder and into the other, thus balancing the pressure upon the two columns.

The rudder is bound up to its work by the two opposing columns; but, as danger would result from too great rigidity, the after cylinders are fitted with concussion rams, loaded with springs which immediately yield to any sudden blow the rudder may receive from the sea, but return as quickly to their original position; thus the blow is not felt at the wheel. These concussion rams also allow for expansion through variations in temperature, and, in case of leakage, obviate the loss of power or backlash by moving in.

* The measures throughout this paper are given in metres. The value of g, expressed in metres, is 9.8088. Metres may be roughly converted into yards by adding ten per cent. This is quite near enough for all the purposes of this paper.—*Translator.*

MASONRY.*

From "The Building News."

Masonry we find rather tersely described in dictionaries as "the art of laying bricks and stones in walls." Now it will be plain to the most casual thinker that this description could hardly be more vague and incomplete, as it omits all mention of the equally important art of stone-cutting. It is obvious that the skill and care of the mason is shown no less in the true and economical working of the stone than in the placing of it in its ultimate position in the work. How much of the mechanical perfection of a complicated piece of masonry, such as a groined roof, the arch of a skew bridge, or a traceried window, depends on the accurate working of each stone, needs but little argument to show. But it will perhaps be thought that this remark as to the meaning of the word as given in ordinary dictionaries is after all only "raising giants to knock them down again," so I will proceed with the immediate business of this paper, which is, firstly, to give a few remarks on the more ancient styles of masonry; secondly, to give as far as I am able, some practical information as to the various classes of masonry in common use at the present day; and, lastly, and more especially for purposes of reference, to give a few extracts from specifications in which the different kinds of work are specified, and which have been actually worked from. As to the first of these, if I were to attempt to give you even a slight sketch of the origin and development of the mason's "craft," as shown by examples of successive ages and nations, it would overtask my ability and the patience of my audience. In this part of the subject, therefore, my remarks have reference generally to work to be found in our own country, and even in this comparatively limited portion of the subject, there is, in an examination and description of the various ancient works in masonry to be found in England, a subject which cannot fail to repay the research of any one who will go into it. Of the few examples to which I shall refer to-night, the first in order, both of importance and date, is the great Roman wall which was built across the Northern part of England, to protect the provinces under Roman rule from the incursions of the Picts and other tribes from the more northerly part of the island. The first of these barriers was built by the Roman Governor Agricola, and was a wall or ramport of earthwork, with nineteen forts or bastions in its length. Severus, finding this earthwork insufficient, constructed the stone wall which still bears his name, and it is also called in the Ordnance maps "the Picts' wall." It stretched from sea to sea, from westward of Carlisle to eastward of Newcastle-on-Tyne, a little to the north of the Newcastle and Carlisle Railway, and, roughly speaking, parallel to it. The face of the wall was of ashlar work, of stone from the immediate neighborhood, and this was backed by walling of Roman bricks (really flat tiles of about 1 ft. square and 1½ in. thick.) The wall itself was 8 ft. high, 12 ft. thick, and about 100 miles in length. Among the other remains of Roman masonry in England, I may mention the ruins of Richborough Castle, Kent; a gateway in the City of Lincoln, and portion of the entablature of a temple which was discovered some years since in excavating for the foundations of a house in Bath. In the year 1869 it will be remembered that the lower portions of some Roman walls and tesselated pavements were discovered in the Poultry, London, the pavement being about 19 ft. below the level of the present roadway, and consisting of a parallelogram about 13 ft. by 12 ft., exclusive of a semicircular northern end. The portions of the walls then remaining were built of tiles, ragstone, and chalk, resting on a chalk foundation. Under the site of the old East India House, Leadenhall street, in 1863, some more Roman walling was found, built of chalk and ragstone, with double bonding courses of Roman bricks. There have been many other portions of pavement and walling discovered of late years, more especially along the course of the old Walbrook; but time will not allow me to say more of them now, except that any one who cares to read about them will find in the description published by the London and Middlesex Archæological Society the most full and accurate information. Of the masonry remaining from Saxon times, the most reliable is to be

*Paper read before the Civil and Mechanical Engineers' Society, by Mr. C. A. Rew.

found at Coningsborough Castle, Yorkshire; the churches at Earls Barton, Brixworth, and elsewhere in Northamptonshire; Barton-on-the-Humber, in Lincolnshire; Sompting, in Sussex; and Clapham, in Bedfordshire. There are many others in different parts of the country, but they are less important, and of less certain date. The leading idea of Saxon masonry seems to have been the building of the quoins or angles with what is known as "long and short" work, the stones being built, as the name implies, with one long one standing on its end, and then a short one bedded in the natural way to act as bond. The general walling was of rag or common rubble-work, sometimes pointed and left with the stones showing, at other times having the "long and short work" set forward enough to act as stopping for the plastering or "rough-cast" with which the tower or wall was to be finished. The reasons for the use of the "long" stones apparently was that they presented fewer angle-joints to the inroads of the weather, and as they were to serve sometimes as stops and guides for the finishing coat of "rough-cast," it might have been thought desirable to have as many long smooth lengths as possible. In the Saxon tower of Sompting, to which I alluded just now, the tie of the alternate stones is to all outward appearance quite lost; the stones look as if the areas of all the beds were the same, and they look like narrow angle pilasters. Whether they are formed for appearance' sake with parts of the faces cut back so as to leave a projecting half-face at the angle, is a point upon which I have never been able to satisfy myself. The next change in architecture and masonry took place in the time succeeding the conquest of this country by the Normans. The older portions of the Tower of London, the ruins of Rochester Castle (by the same architect, Bishop Gundolph); S. Botolph's Priory, Colchester; Iffley Church, Oxfordshire; and portions of the Cathedrals of Canterbury, Lincoln, Winchester, Exeter, and other cities, all afford rich opportunity of study to both architect and mason. In this period the chief point to call for remark is the discovery or introduction of the chisel, in lieu of the axe or stone-hammer. The difference in the work consequent on this change was what might have been expected; for instead of the rough, flat, and chopped effect which characterizes Early Norman work, we find the bright and crisp look which only the chisel could give. The difference was indeed so great, that the chronicler Gervase, speaking of the ornaments of the rebuilt Canterbury Cathedral, after it was destroyed by fire, explained it by saying that "There (in the destroyed building) the arches and everything was plain, or sculptured with an axe, and not with a chisel." About this time, also, if not actually consequent upon this introduction of the chisel, came about a change in the mode of bedding or setting the stones of ashlar work; for whereas the joints were before this of great thickness, they were then reduced to the thinness now generally adopted. Then followed the gradual transitions from Norman to Early English, from that to Decorated, and so on through Perpendicular to Tudor. But these were more purely architectural changes, the masonry, for all practical purposes, remaining nearly the same. There is one note of warning to be derived from the last mentioned style. The masons of the sixteenth century had certainly reached the highest point in the knowledge of constructive stonework, but they substituted lintels or beams for arches in the spanning of openings, and this was one mark of the debasement of the style. Whether the almost universal introduction of iron girders into bridges, from which we are now suffering, will prove the engineering of our own day to have been fully worthy of the title, must be left to the consideration of those whom it most concerns. I think it is undeniable that the period in which the best work was done, more especially in architecture, was the time in which Early English and Early Decorated work were done—chiefly included in the thirteenth century. It must not be supposed that there was not bad masonry done even then; but the masonry of that period, taken as a whole, was, in its mechanical perfection, in the vast amount of scientific knowledge it displayed, and the true appreciation of the nature of the materials used, about as near perfection as it is given to human work to be. The same may be said of all the art and building work of that time. Architectural decoration and sculpture, stained glass and metal work, all bear the marks of the same true art-instincts; and certain it is that if we want in our own day to produce good work, it must and can only be done by aiming at the same principles, and applying them to

practice in the same common-sense way that these great early builders did. With these remarks on the masonry of former times, I will now proceed to treat of the more practical side of the question, and this will be done best by considering it as coming into the three divisions—walls, piers, and arches.

Walls.—The essential conditions of good solid walling are: Firstly, that the stones should be laid on their quarry-beds, *i.e.*, with the natural bed at right angles to the direction of the pressure the finished work will have to bear. Secondly, that every joint and interstice should be absolutly full, and flushed up with mortar, and that, to obviate the too rapid absorption of the water in the mortar, the stones should not be put into the work too dry. Thirdly, that the work shall be so built as to get the best bond possible with the materials at command, which is to be obtained most effectually by the frequent use and even distribution of "headers" or through stones over the whole surface of the wall. Some authorities give as the right proportion that one-third of the whole area should consist of the ends of "headers," but in actual practice it is often specified that there shall be one header in every 4 ft. or 5 ft. run of a course not exceeding 12 in. in height. Care should be taken that, so far as possible, every header should go actually through the wall, and not be what are called "shiners," *i.e.*, simply stones set on edge with the natural bed to the face of the work. The largest and best stones should be reserved for exposed parts, such as quoins, reveals, and doors of windows, etc., not only because they are more exposed to the weather, but because every quoin stone is really a "header" and a "stretcher" too, and every building does benefit greatly by having good strong solid angles. Masonry for walls is either of "ashlar," "block-in-course," or "coursed" or "random" rubble. Of these, "ashlar" consists of masonry in which every stone is wrought on all its sides, and generally to specified dimensions. The top and bottom of the stone are called "bed-joints," the side to be left exposed is the "face," the opposite to it is the "back-joint," and the sides that will be across the wall are called "side-joints," or merely "joints." If the faces of the stone are worked beyond the first cutting it makes what is called "plane ashlar;" if it is figured it becomes "tooled" or "chiselled" ashlar; and if the main faces of the stones project beyond the mortar joint, it is called "rusticated." Whichever of these finishings for the face be adopted, a chisel draught should be carried round the edges, so as to insure straight arrises, and consequently accurate setting of the stones. The way in which "ashlar" work is specified will be seen from the following extract from the contract for the river wall in front of the Palace of Westminster, which is extracted from Donaldson's "Specifications." After specifying the kind of granite to be used, it is specified that:—

"The stones are to be fine-axed on the face to the true curve of the wall, so as to present a fair and perfect surface, at least equal to a sample which will be shown to intending contractors. The beds and joints are to be full and square for their whole depth (particular care being taken to preserve their outer arrises), so that when set the work may be close and solid throughout, without any packing, and no joint exceeding $\frac{1}{8}$ in. in thickness. The backs are to be scappled with a pick, and with a fair surface to receive the brick-work. The courses to be of the height figured, and to be laid with one header to two stretchers; the heading-stones are not to be less in length of face than the height of the courses of which they are to form part, nor less in depth of top-bed than double the height of the said courses. The stretchers are to be not less in length than twice the height of the courses wherein they are to be inserted, nor less in depth at top than the height of the said courses. The bond in the vertical joints is not to be in any case less than one-half of the height of the course immediately below them."

"Block-in-course" masonry is what is commonly used for the spandrels and wing-walls of bridges and other similar works. It is in some respects similar to ordinary ashlar work, only that the stones are smaller, and the courses are thinner and vary in height. In Donaldson's book, in a specification of dock work, it is described in this way:—

"The whole of the exterior masonry to be of blocked walling, drafted and set close in stone-colored lime, the stones for the 3 ft. walls to average from 9 in. to 11 in. on the bed, and about one-fourth to be 2 ft., so that they may tail into the stones on the opposite side. The wall to have, where re-

quested, a through stone of the full thickness of the wall. The interior to be filled in solidly, and rendered over at each course."

In "coursed rubble" the rule generally is, and always ought to be, to place the headers along the last-finished course, at about the right distance apart, and to see that the headers of one course are not directly over these of the course below, and then to build up the short lengths of wall between with the smaller stones. Each stone should be set with the largest side of its natural bed downwards, and completely bedded in mortar as the work proceeds. The back joint should also be, if possible, of the same area as the face. "Coursed rubble" is described something in this way:—

"The external walls are to be built of the heights and thicknesses shown on the drawings, on proper footings, and built in random courses varying from 5 in. to 17 in. deep, well flushed up, and through-stones inserted at intervals of about 5 ft. in every course. The external surface about the ground-line to be neatly hammer-dressed, and the joints pointed with black beaten-ash mortar, and close joints formed next the stone-dressing," (*i.e.*, jambs of door and window openings, quoins, etc.).

"Random" or common rubble is simply work obtained by using the stones just as they come from the quarry, with any very shapeless angles or projections struck off with a hammer. In addition to these there is "flint rubble," which is much adopted in chalk neigborhoods. This is done either with the stones as they come to hand, or just roughly squared, in which latter case it is called "snapped" flint-work. Properly put together, this work is practically everlasting, as many church-towers and other buildings still are standing to testify. Among the sea-defences of Brighton, there is a groyne built of this flint rubble backed by cement concrete in mass. The casing-blocks were made in moulds of the required shapes. The flints, which were specified to be of not less than 6 lbs. weight, were thoroughly washed, and built into these moulds by hand, set in Portland cement. The blocks of which the interior of the work was mainly formed were of ordinary Portland cement concrete, set as masonry up to the low water of neap tides, the remainder of the core (if I may so term it) being of Roman cement concrete, thrown in from a platform above. It has stood for nearly ten years, without, I believe, costing a shilling to repair; in fact, so far is its success assured, that the Corporation of Brighton have ordered their Engineer Mr. Philip C. Lockwood, to proceed with the erection of another on the same plan. Having said thus much on the masonry of walls, I come now to that of Piers and Columns.

Piers and Columns.—Of these, so far as the piers of bridges and viaducts are concerned, it may be considered that they are but short pieces of walling placed transversely to the main line of the structure, with the top courses bevelled to form skew backs for the arches, and with ends either square, pointed, or circular, as the case of the designer may dictate, or the circumstances of the case demand. But as far as their masonry is concerned, they require no elaborate description. Where they take the form of columns, very great additional care is required to guard against accidents, such as befell the granite columns of the Holburn Viaduct. The most important point is, that the bed-joints should be dressed to perfectly true and horizontal surfaces, as, if the joint is not in a plane, it must be either concave or convex; if the former, the pressure is brought solely on the edges, with the only possible result that the edges get fractured by the scaling of one or both of the stones; and if the latter happens to be the case, the stone, instead of bearing the weight equally over its area, is carrying it on one or more projecting portions, involving crushing and consequent settlement. It is a very common prejudice that every pier or column should, if possible, be built in single-stone courses; but there are those who hold that even stronger work may be obtained by making the courses to consist of two or more stones, with a single-stone course here and there. In some cases, such as the pillars between the nave and aisles of a church (where single stones are mostly used), seatings of sheet-lead are often inserted, or the joint is widened by means of a draft being sunk round the circumference of the bed of each stone. The danger of building large piers and columns is that the work in the interior will be "scamped." As an instance of this, I need only refer to the tower and spire of Chichester Cathedral, which "came down with a run" some few years since. The large angle piers were of apparently good face-work, but the internal portion was

built of rubble, and "scamped." In the church at New Shoreham, the columns were, I believe, cylindrical and octagonal, and so remain on the north side; but for some reason—apparently the desire to substitute a waved line for the cylinder—a ring or casing of masonry was built round those on the south side. This averages about 6 in. thick. Whether there is any bond between the original and the addition is not clear, but the last time I was in the church some of the stones were so loose that one could remove them and see the old face inside. These are examples of old work which are more valuable as warnings than anything else, for they go to impress upon us the vital importance of proper bond and solid backing, more especially in detached portions of our work. From the pier or column our attention turns naturally to

The Arch.—The masonry of a square stone arch is, of course, just so much ashlar, built of stones whose beds converge to a common centre, and the soffits and back joints of which are worked as segments of circles struck from the centre. It is a good rule in stone-cutting to work the largest face of the stone first; and this, as we have seen, is generally one of the beds; so, in the arch stone, this bed being worked, the ends or heading joints are squared from it, then the section of the stone is marked on the ends from a template, and the workman can then cut the other bed of the stone. Having got so far, he sinks drafts at each end of the soffits, then works the soffits to these drafts, and the stone is ready to be built into position. This description refers more to the working of the ordinary voussoirs of an arch; but in those for the face there is also the consideration whether the back-joint as well as the soffit shall follow the curve of the arch, and so all the stones show similar forms on the face (as is always the manner in Gothic work), or whether they are to be stepped (as is often the case in Classic work). In the latter case the spandrel must be worked in diminishing courses, the heights coinciding with the steps before-mentioned. In arches forming an arcade it is common to bed one or two of the stones with level beds, but this does not do after the arris gets of too acute an angle. They are sometimes done with level beds up to the point at which the extrados of the arch crosses a line set up perpendicularly from the point of the soffit-springing; but I think this is a defective construction. So far we have been considering only the building of the plain cylindrical or pointed arch; but there are two complications of these which would, either of them, form quite a sufficient subject for a paper—I mean the construction of skew arches and that of groined vaulting. Oblique or skew arches were comparatively unknown in England until the development of the railway system obliged engineers to turn their attention to a means of carrying their new lines of communication over and under old ones that they might have to cross, and this at any angle such crossing might happen to be. Some clumsy attempts were made to meet the difficulty by making the abutments of sufficient length at alternate ends to give a square arch so long that the lines of rail fell within those of its ends. This sort of thing could hardly be expected to be the rule for any length of time, and to a Mr. Storey belonged the honor of being one of the first to build a real skew bridge. He built in the year 1830 a bridge near Durham, of which the direct span was 12 ft. and the oblique span 42 ft., so that the bridge was at a very acute angle. It is necessary in building skew arches that the coursing joints shall be square with the face of the arch, as they naturally would be in a square one; and here arose the problem of how to work the winding of the courses spirally over the centre, for the coursing joints must revolve, as it were, round the cylinder of which the centre formed part, just as a straight slip of paper will go round a cylindrical ruler or a roll of plans. The problem was worked out and investigated in the first instance by Mr. Peter Nicholson, but the best and most concise book is that published in 1839 by Mr. Buck. In small arches, a practical way of setting out the work is to have a long pliable strip of wood of sufficient length to bend over the centre along the line of the face of the arch, and to divide this line into as many equal parts as you mean to have courses of masonry. Then, with a T-square having a long flexible blade, the coursing-joints can be set out with quite sufficient accuracy. For arches of more considerable span, a much more scientific mode of procedure than this is needed, but the principle still is that the coursing-joints are lines square with the face and revolving spirally over the centre, and that the heading-joints are portions of spirals revolving at right angles

to them. The chief difficulty is in finding the proper forms of the face-stones, for as the lines of the heading-joints are not *exactly* parallel to the face-line, all the face-stones vary from a rectangular plan, which fact also produces another curious effect—viz., that the face-joints are not straight, but very slightly curved lines. There are other plans and rules for building arches of this kind, but they all start more or less from the principles I have alluded to. In considering the subject of vaulting and groining, it may be remarked that however much the Greeks have towered above all other nations in beauty of form in sculpture and decoration, they have left but few remains to show that they possessed much knowledge of the theory of arch-building, unless we conclude that they did know, and that the severe horizontal character of their architecture was entirely contrary to the vertical and aspiring nature of the arch—and with the mastery they did possess of all subtleties of curvature, it seems that this, rather than want of knowledge, was the reason. There is another argument which points also in this direction, which is that all architecture where the lintel is a prominent feature is an architecture of large stones; and where the arch is made much of it is an architecture of small stones; and the former of these was essentially the condition of Grecian architecture. There is still standing a building of about 50 ft. diameter, covered with a dome of about the same height. This is built entirely of horizontal courses, the soffit being formed by cutting away the face of each stone to a template worked to the radius of the vault. The Romans, on the contrary, made features of the arch and the dome. There are in Rome groined vaults of 70 ft. span, and one dome of nearly 140 ft. diameter. The ordinary form of Roman vaulting was a main cylindrical vault, crossed by transverse bays of equal or less span. The rule often was to make the main vault a semicircle, and to stilt the lesser ones until the two crowns were on the same level. The centres were probably made by forming a complete centre for the main vault, and "planting on," as it were, for the transverse bays. This plan is in many ways defective, and gives a waved instead of a straight line of intersection. It was found that the proper mode of construction was by means of regular groin-ribs, and very early examples of this plan are to be found in the rude Norman work in this country. In this there was still the same difficulty of the right form of the diagonal rib still unsolved. The Norman builders tried to manage it by making the diagonal rib a segment, which had a rise equal to the semicircular main rib, but still it was not right; for, as in semicircular vaulting the profile of the intersection is a semi-ellipse, there were little spandrel-pieces to be filled up, which gave the diagonal ribs rather the effect of having settled on their haunches. Then those wonderful thirteenth century people adopted the plan called "plain ribbed vaulting," in which the ribs were first arranged, and then the panels filled in either with thin slabs of stone cut to the ribs, or with small stones in regular courses. In the case of the slabs the panels were horizontal at any line parallel to the axis of the vault; but in the case of the masonry each panel was built slightly concave, thus making every panel an arch which rested on the upper side of the ribs. After a time began the custom of multiplying the ribs, until the panels became so many and so small, that the masons of the sixteenth century reverted to the old plan of building solid groining only, using jointed masonry instead of rubble; and then the ribs and tracery were cut up into the soffits, being sunk into the solid stone. In actual practice, a good way to set out rib and panel vaulting is first to draw the diagonal rib, making that a semicircle; then, with the same radius, draw the transverse and wall ribs. This makes each bay become a domed vault, with the ridge rib rising from the crown or point of the cross-rib to that of the diagonal ribs over the centre of the bay. In English vaulting, the ridge ribs are generally kept horizontal, and in this case it is wise to draw the transverse rib first, and then make the diagonal rib a three-centred arch, struck from the springing with the radius of the cross-rib, and then with such other radius as will give a curve tangential to those so struck, and a complete arch of the same rise as that of the transverse rib. It is very desirable that all the ribs should spring with curves of the same radius, except in cases where the wall-rib is carried vertically to a sufficient height for the introduction of windows of proper form and proportion. The springing should be built up as high as convenient in single stones, and the upper bed finished so as to present skew backs for

the different ribs. The mouldings can then be worked down from the ribs, mitreing and losing themselves one in the other. The intersections of any of the ribs are generally keyed with a large stone, so worked that it will drop far enough through the vault to allow of the carving of the boss, and with proper butt-ends on which to work the rib-mouldings, until they are lost in the foliage or other decoration of the boss. Then the panels are filled in, and the bay is complete. Before concluding I would direct attention to two special examples of masonry, designed for particular conditions, and each doing its work most admirably. The first is a sea-wall, erected at the mouth of the Exe by the father of our President, Mr. Whitaker. It stands in a most exposed situation, not many miles from the unfortunate wall at Dawlish, on the South Devon Railway. There is this great difference between the two walls—viz., that the Exmouth wall stands, while the South Devon wall is generally washed away in parts once or twice in the course of every rough winter. The one is nearly perpendicular, with a bold projecting coping-course. The masonry is built in the ordinary way, the stones having their quarry-beds downwards, and they are set in mortar and pointed. The result is that the mortar gets started from the joints, and allows portions of the waves to drive into the middle or even back of the work, and a kind of lifting or explosive action takes place, which goes on at nearly each wave, and this at the back, with the coping to afford a hold for every extra-strong wave in front. Is it to be wondered at that this wall is a constant source of amusement to spectators, and of expense to the shareholders? The wall at Exmouth is the very opposite of all this, its curved face permitting the easy flow of the water, which runs up and falls back harmless when it does not do actual service by breaking the force of the succeeding wave. This wall has cost hardly a single shilling in repairs since its completion some thirty years ago. The stone used was limestone, from the neighborhood of Plymouth. The courses are placed vertically instead of horizontally, and the stones are united only by pebble dowels, no cement or mortar of any kind having been used. The result of placing the stones on their ends was that only the smallest possible superficial area was presented to the lifting action of the sea. Judging by the test of actual experience, there can be no doubt that this system of walling, for sea-work, leaves nothing to be desired, for it has stood, without the starting of a single stone, through storms that have swept clean away walls built with ordinary masonry. The other special instance to which I would refer is that of the beautiful system of dovetailing pursued by Smeaton at the Eddystone lighthouse. It must be plain to all how exactly fitted to its purpose it is, and how perfect and complete in itself is each course. I have tried to analyze the system on which the joints are planned. Smeaton divided the circumference of the lighthouse into sixteen equal parts, and then the face of each alternate stone into five. By drawing radii through the edge of the stone and the outer fifths, the lines are found which give the width of the dovetailed joints. The diameter he divided into nine parts; the central ninth forms the well-hole. The depths of the stones from front to back are, as near as I can measure, exactly ninths of the diameter also. The single stone surrounding the well-hole has the extreme points of its dovetails on a circle whose diameter is one-third of that of the course. It is formed by getting the largest square possible into this circle, and then, by bisecting the four bounding segments, the other points are found; these are joined alternately by lines parallel to the sides of the square, and the dovetails are formed by lines converging to the centre. What this should show us is that in all good engineering, as in all right architecture, it is on the careful study and mastery of detail, no less than to the first general conception of the work as a whole, that its real and ultimate success must depend.

The cars of the Burlington and Missouri River Railroad Company have an iron plate running the whole length of the car between the floor and the windows, which is much better than the old plan of wainscoting this space in wood, as the wood shrinks and leaves cracks through which thin drafts of air strike the feet of the passengers. The iron belt is intended to obviate this difficulty. The company is changing about seventy-five of its flat cars into coal cars for the transportation of coal from the Iowa mines eastward.

ON A MINING TRANSIT AND PLUMMET LAMP.

By R. W. RAYMOND.*

From the "Engineering and Mining Journal."

Having had recently the opportunity of examining a transit and a plummet lamp, manufactured by Messrs. Heller and Brightly, of Philadephia, and intended for the use of mining engineers in underground surveying, I thought a description of them would be interesting to such of our members as have work of that kind to do, and accordingly I requested the makers to prepare and send to me a detailed account. There is nothing specially novel, I may remark, in the construction of the transit; its claims to favor must rest upon its compactness and lightness, together with the general excellence of its workmanship. The principal peculiarity is the ribbing and flanging of the parts requiring strength, so as to dispose the minimum amount of material where it will secure the greatest rigidity. This transit is said to be the lightest of American make. I believe Caselli has sent some from London which are still lighter; but they are perhaps not so completely furnished for field-work. I confess I do not see how the weight can well be reduced any further, unless an instrument could be made of aluminium—a plan which Mr. Rothwell once suggested; but which may not, perhaps, be entirely practicable, and, at any rate, has not been tried.

The following is the manufacturers' description of this transit, which they have designed and introduced within the last year:

It is a small, portable angle instrument, similar in principle to the ordinary "engineer's transit," and a *fac-simile* in every respect (excepting size and weight) of their "complete engineer's transit." It has long compound centres; the horizontal limb is read by two double opposite verniers, placed outside the compass box; the vernier openings in the plate being made very wide, so as to allow the easy reading of the graduations. There is a three-inch magnetic needle, and its ring is divided to half degrees. The telescope is $7\frac{1}{4}$ in. long, with object glass $1\frac{5}{16}$ in. in aperture, and shows objects erect and not inverted. A sensitive level, $4\frac{1}{2}$ in. long, is attached to the telescope for reading angles of elevation and depression, etc. The tripod is furnished with an adjustable head for precise plumbing of the instrument over a centre; and the wooden legs of the tripod are made in such a manner as to form one leg when folded together. The plates, vertical circle, etc., are provided with clamps and tangent-screw movements; and the clamps on the axis of the telescope are arranged with sighting slits and indexes, so as to answer also for right angle sights. The numbering of the compass ring and horizontal limb, instead of being in quadrants from 0 deg. to 90 deg. each way, as usual, is a continuous one, or from 0 deg to 360 deg.; but every quadrant of the horizontal limb is also marked with its magnetic bearing, *i. e.* from 0 deg. N. to 90 deg. E., every ten degrees is marked N. E.—from 90 deg. E. to 180 deg. S., every ten degrees is marked S.E., etc. The advantage of this arrangement is, that if at starting, the vernier of the horizontal limb be set to read the same bearing as the needle, the needle can be screwed up, and both the angles and magnetic bearings read from the horizontal limb, without using the needle for the remainder of the survey, thus precluding any error from local attraction, reading from the wrong end of the needle, or loss of time in waiting for the needle to settle. The telescope, though short, is a very powerful one, magnifying and having the clearness of an ordinary 17 in. level telescope. A reflector for illuminating the cross-wires in dark places is used, as is also an extension tripod leg for lowering or raising the instrument. All the working parts of the needle-lifter, clamp and tangent-screw movements, are concealed between the plates, making the instrument more compact. A prism and tube for attaching to the eye-piece of the telescope, for sighting vertically in shafts, is also furnished. The weight of the instrument, exclusive of the tripod, is about $5\frac{1}{2}$ lbs.; the weight of the tripod is $3\frac{1}{2}$ lbs.; the height of the instrument from the tripod legs is 7 in.; the extreme diameter of plates, 5 in.; the diameter of the horizontal plate at the point where verniers and graduations meet, $4\frac{1}{2}$ in. The instrument and tripod head are

*A communication to the American Institute of Mining Engineers, at the Boston meeting, February 19, 1873.

packed in a box 7½ in. square, arranged with straps to allow its being carried over the shoulder in the same manner as an army officer's field glass, while the folded tripod legs answer as a cane. Though these instruments have been specially designed for mining use, yet from their lightness and compactness they are also meeting with favor for geological surveys, and for preliminary railroad reconnoissances; when used for these purposes, an extra pair of hairs for stadia purposes (*i. e.*, measuring distances without chaining), besides the ordinary cross-hairs, is added.

The same manufacturers make a very convenient plummet lamp, for underground work. It consists of a brass lamp, suspended by two chains, and terminating below in a conical plummet. The so-called compensating ring is an equatorial ring, surrounding and supporting the lamp, which swings freely within it, upon an axis. The two chains are attached to this ring at the extremities of a diameter perpendicular to the axis. By means of this arrangement, the point of suspension, centre of lamp flame, and steel point of plummet always lie in a true vertical line, no matter how much the brass supporting chains may alter in length from the heating of the lamp, kinking or wearing of the links. A shield at the top prevents the flame from burning the string. These lamps are generally used in pairs for back and forward sights.

I understand that Mr. McNair of Hazleton and Mr. Coxe of Drifton, both members of this Institute, have used this instrument with satisfactory results.

ON THE PRESERVATION OF WOOD BY MEANS OF TAR.

From the "Moniteur Scientifique" through the "Builder."

In a previous number, says the "Moniteur Scientifique," we published a memoir on the preservation of timber for purposes of construction. All the methods of preserving wood hitherto in use were therein noticed; but whilst some were treated at considerable length, others were touched upon very slightly. In the latter category was the preservation of wood by means of tar. We believe it may be of service to our readers to treat the subject more fully, and we have, accordingly, availed ourselves of the writings of M. Melsenns, member of the Académie Royale de Belgique, of the Philomathic Society of France, etc.

In August, 1848, M. Melsenns directed attention to certain facts connected with the conservation of wood with the aid of substances insoluble in water and unalterable under the ordinary influences of atmospheric air and moisture. The type of these substances chosen by M. Melsenns was resin, pitch, and tarry products generally, such as we find unchanged after a long succession of centuries in Egyptian mummies.

In a subsequent number of the "Bulletin" of the Belgian Academy of Sciences, the same learned writer gave an account of some experiments instituted by him and of the results thence obtained. These we propose to review briefly.

In the winter of 1840-41, M. Melsenns prepared some blocks of wood 40 centimetres (14.9 in.) long, and 25 centimetres (9.2 in.) in thickness, which were thoroughly impregnated with gas-tar, by a repeated process of heating and cooling. These prepared blocks were then buried in the corner of a garden, where the soil was saturated with the drainage from a urinal; there they remained for a couple of years. When taken up and split open, they were found to be perfectly sound.

In the cross-sections white bands or streaks were observed showing the places into which the tar had not penetrated; it was observed that the latter had followed the sinuosities of the woody fibres. The split-blocks were separated in halves—one set of halves was retained, and the other buried for some time in ordinary soil. The first set of halves was kept from exposure for eighteen months: the pieces were then plunged into a steam-bath at a temperature of 100 deg. Cent. (212 deg. Fahr.); suddenly cooled by plunging them into cold water, and set out in the frost; they were then laid out for some time uncovered on the damp surface of a lawn; then placed on the parapet of an isolated building; lastly, they were buried in a mixture of sand and mortar under a butt holding rainwater. It would be difficult to suggest or imagine a concatenation of circumstances more favorable to decay, than the alternations of dry-

ness and humidity to which they were thus continuously exposed. But, according to the reports of all who inspected them, they were perfectly sound and uninjured after *twenty years'* trial.

M. Melsenns also gave portions of the same blocks to M. Rottier, who placed them in his rotting-vats. He reported to M. Melsenns as follows:—"Small portions of your blocks were destroyed in my vats at the expiration of 240 days or thereabouts; but it should be observed that blocks of a precisely similar description, and not so prepared, lasted 120 days at furthest.

These facts deserve the attention of railway directors, who still not unfrequently neglect this department of their service. With M. Melsenns, we regret that experience acquired in this matter on lines of railway is not always made public. The Belgian Government, for example, tried a dozen different methods of preserving wood; but a special Commission appointed to investigate the subject was directed to devote its attention to the following matters:—1. The durability of oaken sleepers in their natural state, and impregnated with creosotic oils by Bethell's process. 2. Ditto, of blocks of beech and red deal prepared in a like manner. M. Melsenns also observes that it is to be regretted that the reasons which led to the abandonment of the "Boucherie" process on Belgian lines of railway since the year 1859 have not been given in the reports of the railway administration, as such reasons would have afforded reliable data for future experimentalists to go upon.

Useful information might be obtained in another way. We know that the renewal of the material is most frequent with certain woods and upon certain lines of railway, and we are disposed to agree with the observation made by M. Melsenns in 1848, that "an exhaustive study of all the circumstances that contribute to render the wood unserviceable under such cases would infallibly lead to the solution of this great question; at any rate, careful researches into the more immediate causes could not fail to be of infinite value."

In a pecuniary point of view the subject is of no small importance. During the three years, 1861, 1862 and 1863, over 140,000 sleepers were put *hors de service* on Belgian lines; in 1860-62 the number was 150,000; so that there is no exaggeration in assuming that the future expenditure may be reckoned at 150,000, which, at 5 francs a piece, represents a sum of 750,000 francs (£31,250). It must be understood, that up to 1864 not more than one third of the sleepers on the Belgian lines were prepared in any way. Of course the estimate above given must be reduced as the proportion of the prepared sleepers becomes greater. However this may be, the total number renewed between 1839 and 1862 was 1,849,781. Of these, 1,081,000, at 5 francs each=5,405,000 francs; 761,000 at 3¼ francs each=2,885,000 francs; making a total value of 8,290,000 francs (£331,600). But the question is by no means as simple as it appears here; neither would it be all unalloyed gain if the sleepers lasted for an indefinite period.

M. H. Maus published an interesting paper upon the subject in the "Annales des Travaux publiques," vol. iv., 1846. Without going minutely into the details, we may observe that, according to M. Maus, the annual cost of a sleeper is made up of two separate elements,—1, interest on the prime cost; 2, an annual reserve, which at interest should reproduce the sum required to purchase a new sleeper when the time comes. On this point the reader may consult M. Maus's paper, and the accompanying table, based upon a formula prepared by M. Emery. The formula, however, needs completion. As it now stands, no account is taken of the money-value of the discarded sleepers. The sound portions of oaken sleepers, for example, may often be turned to account for other purposes along the line,—fences, barriers, posts, and such like, and for fuel. Sometimes a discarded sleeper purchased in a good year will fetch as much as the price of a new one; but, as a rule, they are not worth much. As fuel, a sleeper prepared with gas-tar will be valuable in proportion to the tar contained in it. Hence, the data in M. Maus's table are not altogether exact, and must be taken as representing the *maxima* of result. In every case, however, the cost will be less in proportion as the durability of the sleepers individually is greater.

A correct formula could only be prepared with the aid of long experience in the working of lines of railway, due regard being paid to all the conditions involved, such as the cost of labor in laying and replacing, the choice of the wood, the prime cost and the durability of each sort, the nature of the soil in each case, etc. The cost of pre-

paration should be as much less in proportion as the wood in its natural state is more durable. The hesitation of the railway authorities and the need of experience are explanation sufficient of how it came to pass that in 1864 only 37.77 per cent. of the sleepers on Belgian lines of railway were prepared in any way.

A section of a piece of timber impregnated with tar presents some curious and very distinctive characteristics, according to the duration of the process of injection and the amount of tar injected. In every case the injected tar follows the lines and sinuosities of the longitudinal fibres. When injected in sufficient quantity it fills the pores altogether; when, on the contrary, the process has been incompletely performed, which, however, is generally sufficient, the tar accumulates in the transverse sections, and plugs the channels that give access to deleterious agents.

In the large blocks of beech and other soft woods, bands were observable marking where the tar had not penetrated. Still, despite the severe test to which they were exposed, these blocks kept sound at a very slight depth below the surface of the ground.

It should be remarked that it is always best that the wood should be put in shape, and in sleepers, that the mortises for receiving the chairs, and the holes for the dowels, wherewith the latter are fixed, should be made before injection.

The experiments made by M. Melsenns on oaken blocks, exposed to the fumes of liquid ammonia, show that the conservating fluids follow the precise course that would be taken by decay. To our great regret, want of space forbids us to follow the author into the details of the experiments executed by him, or to reproduce the figures given in the original memoir. Suffice it to say, that in wood thus treated, the tar acts on the very parts first exposed to injury, and on the course that would be taken by decay, which is thus rendered impossible. We may add, that a working engineer, with whose assistance M. Melsenns attempted to split the blocks thus prepared, considered the resistance equal to, if not greater than, that of ordinary oak. Several small nails, in the substance of the wood were found entire, and not at all rusted—a peculiarly favorable circumstance that deserves to be specially noted.

Whatever the nature of the wood, rot, wet or dry, spreads rapidly in the direction of the *length*; its transverse progress, in the direction of the medullary rays, is less rapid. Sleepers are thus often thoroughly rotten, although the outside shell may appear sound and uninjured. We frequently find them decayed in the lines of prolongation of the dowel-holes, and yet sound everywhere else. When sleepers are not dressed, the process of decay is observed to be delayed in all ordinary woods. In oak, where the fibres run in the direction of the dowel-holes, the portions of the wood below the latter are often stained black with a sort of ink formed by the rust of the iron dowels acting on the tannin in the substance of the wood. These blackened lines do not run straight, but in each case follow the line of the first series of longitudinal vessels reached.

Saw and hatchet cuts, and all other injuries causing a solution of continuity in these logitudinal vessels, tend to expedite decay. In 1843--44, when the wooden pavement in the Rue Croix des Petits Champs, in Paris, was taken up, all the blocks left exposed on the ground were decayed at top and bottom; an injection of tar, however incomplete, would have prevented this injury to the wood.

In his "Memoir on the Conservation of Wood" ("Bulletin de l'Académie Royale de Belgiqué"), M. Rottier has endeavored to determine by which of the numerous substances contained in coal-tar, this special action is exerted; but, whichever it may be, the experiments of M. Melsenns sufficiently testify to its practical utility. Neither need we lay too great stress on the substance with which the wood is to be impregnated, so long as it will not volatilize except at a high temperature.

M. F. Kohlmann ("Comptes Rendus," June, 1863) has directed attention to the employment of tar in the conservation of every description of building material. He shows that tar, or, better still, pitch, stearic acid, and the like, might be substituted for water in mixing plaster, and that the admixture, although mechanical, is so intimate that the benzine, and other substances in the pitch, are often found imperfectly crystallized in the plaster. The process of impregnation with gas-tar above described, must have a somewhat analogous effect, as M. Rottier found that chips thus treated would not bleach under the action of ether. They remained of a deep brown color, and

under the microscope, the woody fibre of the cells was found to be stained with the tar.

However this may be, M. Kohlmann ascribes the practicability of employing these substances in plaster, in place of water, to the property they possess of intermixing intimately therewith. The experiments of M. Melsenns show that neither mercury nor sulphur possesses this property.

In the specimens of injected woods exhibited in 1848 were pieces impregnated with mercury, with sulphur, and with "Darcet's metal." It would be interesting to ascertain to what extent timber thus prepared might be employed in shipbuilding and in mines. As regards woods impregnated with fusible alloys, their economic value is very small, being limited to marqueterie-work and the like.

Everything tends to show that the conservation of wood deserves a place in the foremost rank of questions affecting public economy, and that up to the present time the subject is very far from having received a satisfactory solution. A sleeper should last as long as a mummy.

The methods of injection suggested by M. Melsenns in 1845 did not answer equally well with every kind of wood. After trying wooden blocks in every sort of condition,—dressed and in the rough, green and dry, sound and decayed, M. Melsenns found that alder, birch, hornbeam, beech, and willow were easily and completely impregnated; deal sometimes resisted the process, the innermost layers remaining white; poplar and oak offered a very great resistance,—indeed, with poplar it was found necessary to repeat the process.

In oak it often happens that the sapwood, or its outermost layers, are impregnated, whilst the tar has penetrated a few millimetres only into the rest of the wood. A very large block of oak, very imperfectly injected, in spite of a twenty-four hours' sojourn in a boiler, at a temperature of 120 deg. to 140 deg. Cent. (248 deg. to 282 deg. Fahr.), was left out through the winter. The workman called upon to examine it afterwards reported that he had never seen harder or drier oak. It had then been eight months in the open air. It was examined in the April following the severe winter of 1847.

It often happens that considerable portions of the wood will resist the passage of the tarry matters, but the interstices being stopped through certain parts of their length are thus rendered inaccessible to decay.

According to the nature of the wood and the manner in which the injecting process has been performed, the wood will absorb from 30 to 50 per cent. by weight of tar, when perfectly dried *in vacuo* at a temperature of 140 deg. Cent. (284 deg. Fahr.) This would no doubt involve considerable expense; but in most cases, as with sleepers, a thorough injection is not requisite, and the process may be repeated when signs of decay begin to show themselves.

The Belgian railway regulations require that a sleeper impregnated with tar should retain 9.25 kilog. of it. It is difficult to see why a dozen kilog. of tar, deprived of all its volatile ingredients at a temperature of 150 deg. Cent. (302 deg. Fahr.), should not do as well as ordinary coal-tar. In the experiments with creosoted fir sleepers, it was found that 30 to 40 kilog. of wood absorbed 22.5 k. of tar.

The experiments on which M. Melsenns has based his assumption of the sufficiency of a *superficial* injection of hot tar, were executed with fifty pieces of board 0.30 m. long by 0.07 m. broad by 0.05 m. in thickness. The period of immersion in the hot tar varied from 15 to 20 min. The matters employed were ordinary gas-tar, and gas-tar deprived of its volatile ingredients; sometimes resin was added. On coming out of the hot tar, the boards were plunged in cold liquid tar; afterwards they were dried in a hot bath. Oak, fir, beech, hornbeam, and poplar were used.

Wood in its natural state, from the Veterinary School, where it was more damp than in an ordinary store, was prepared, dried, weighed, placed in boiling water for twelve hours; then left exposed; and weighed from time to time. The results were as below:—

First Series of Experiments.

Average weight of the prepared wood (mean of 20 experiments)	100
Ditto, after immersion in boiling water	120
Ditto, after fifteen days' exposure	107
Ditto, after two months' exposure	94
Ditto, after three months and a half exposure	89
Ditto, after nine months and a half exposure	91

The weights of similar blocks, not prepared, under like treatment, were,—100,

136, 99, 86, 84, 85. A mean of five experiments.

Second Series of Experiments.

Average weight of the prepared wood (mean of 20 experiments)	100
Ditto, after a month in sandy soil, always damp, and sometimes saturated	111
Ditto after two months' exposure at noon-day in the months of July and August	97
Ditto, after six months under cover in the laboratory of the Veterinary School	98.5

The weights of similar blocks, not prepared, and treated in like manner (a mean of five experiments), were,—100, 127, 89.5, and 91.

These data show that wood hastily prepared and very imperfectly impregnated lost and gained *less* moisture than ordinary wood in its natural state, in like times, and under like conditions.

As regards the sort of wood, it was found that oak absorbs and loses least; fir ranks second; beech and other soft woods come third; and hornbeam fourth.

Further experiments in regard of this point would be useful.

Superficial injections with hot tar appear to differ essentially in their effects from ordinary tarring with the brush. Under the microscope, the difference is very strongly marked.

In conclusion, we give M. Melsenns' deductions from the experiments above referred to:—

"We may inject the whole or any part or parts of the wood, green or dry, dressed or in the rough, by preparing it either by chemical agents, or the natural process of seasoning, employing the pressure of steam, or of the atmosphere, as the mechanical power, and heat as a solvent or liquefier of the preserving substance.

"The latter will always take the course that would be followed spontaneously by decay.

"The superficial carbonization of the wood is always more effective when produced with the aid of tarry matters than by the simple action of heat (charring), which decomposes a portion of the wood.

"When the injection is superficial, the wood should always be put into shape first.

"A railway sleeper thus prepared should have a long, if not indeed an indefinite existence, if exposed to the inroads of decay alone; but, in practice, we have to take account of mechanical causes of injury as well."

THE UTILIZATION OF SLAG.

From "London Mining Journal."

A commencement was made in the early part of this week with the manufacture of slag bricks, on the principle recently patented by Mr. Joseph Woodward, of Darlington. It is hardly necessary to inform our readers that the ironmasters of Cleveland have long looked forward to the utilization of blast-furnace slag as a possible thing; but nearly all attempts hitherto made to turn it to good account have proved abortive, and the material was, therefore, thrown away as useless. But it was not alone because of its utter inutility that the refuse of the blast-furnace was a cause of anxiety and concern to the ironmasters. Its removal involved the employment of a large number of hands, whose services might under other circumstances be entirely dispensed with; and not only did this mean the disbursement of a large sum in wages, but also the keep and maintenance of a more or less numerous stud of horses. Nor was this the worst of it. In order to carry on blast-furnace operations successfully it was necessary to procure a good "tip" for the slag, and if a site otherwise eligible did not possess this primary essential it could not be taken advantage of.

In course of years the slag deposit becomes filled up, and although the ironmaster has probably acquired 20 or 30 acres more than he otherwise would have required, in order that there might be sufficient scope for the reception of the slag, he is doomed in course of time to witness the filling up of this waste ground, so that an extension of the site has to be obtained in order to admit of the slag being got rid of effectually. In some cases it has become impossible for ironmasters to obtain suitable ground for an extension of the slag "tip;" and where this cannot be done the scoriæ has to be carried out to sea, or otherwise disposed of at a distance.

In the Middlesborough district attempts have been made, although only on a very

limited scale, to employ slag for road making purposes; and the Commissioners of the Tees Conservancy have used several thousands of tons weekly in the construction of their new breakwater, for which it appears to be admirably adapted. But all this is only a drop in the bucket compared with the enormous accumulation of the useless product wherever blast-furnace operations are carried on; and ironmasters have hitherto looked in vain for any substantial relief from the cost and inconvenience of getting rid of this expensive and cumbersome material. Far reaching deposits of scoriæ are to be found in the neighborhood of all large works, attesting the failure of every attempt to effect its utilization, and yet all practical men are agreed as to the practicability of turning it to good account. Human ingenuity has done great things from much more unlikely materials, and we may fairly anticipate that the day is not far distant when the now despised and rejected product of the blast-furnace will be made a source of profit instead of loss to the manufacturers.

Meanwhile we have to record a very important approach towards the desired end. Mr. Woodward, of Darlington, has patented a plan for manufacturing bricks from scoriæ, and as we indicated at the commencement of this article, the system is now fairly at work at the Eston Works of Mr. Thomas Vaughan. The slag is taken as it comes from the blast-furnace. It runs into a series of moulds, placed at regular intervals on a revolving table. As this table turns on its axis the moulds are allowed to fall to pieces, so as to enable the bricks to drop out. This is done by raising a clamp, by which the sides of the mould are held together. After being removed from the moulds the bricks are thrown into a kiln or furnace close at hand, where they are annealed; and afterwards they are capable of being used in any ordinary structure for which clay bricks are suitable. Having seen several of these scoriæ bricks as they come from the annealing furnace, we feel bound to declare our belief that they will fully answer the desired purpose. Their fracture is close and firm, and they are capable of resisting an intense heat. So far as strength is concerned, they will withstand a crushing force of 3 to 4 tons per cubic inch, or four to five times more than that of common bricks. Another advantage of the scoriæ brick is that it remains unaffected by exposure to the atmosphere. There is a considerable loss by breakage, the bricks often coming to pieces in falling from the moulds, but once they have solidified they are almost, if not quite, as hard as granite. It is calculated they can be made for 8s. per 1,000, or even less, whereas ordinary bricks cost 20s. and upwards per 1,000. In the cost of manufacture there is thus an important economy. A new company has been formed on the limited liability principle to work Mr. Woodward's patent, and they have acquired the right to the slag of all the blast-furnaces on the Tees, including those both above and below Middlesborough. Ironmasters are looking forward with much interest to the results of the new process, which if it were carried out on a complete scale in the Cleveland district would lead to an economy of no less than £60 or £80 per week at nearly every individual works in the North, apart altogether from the saving that would be effected in the reclamation of land now used for the deposit of slag. If we assume, as we fairly may, that by striking an average 20 acres of land will be reserved for this purpose at each works, we will have a total of over 600 acres of land lying waste in the North of England that could be reclaimed and used for agricultural purposes.

It may be well to explain that Mr. Woodward's patent does not introduce us to the first application of slag, or scoriæ, for building purposes. For some time past a somewhat similar process, varying of course according to the altered conditions under which the material is produced, has been in use at Konigshutte, in Silesia, where it has been tolerably successful. Under the latter system the slag is run from the furnace into a hemispherical basin on wheels, the bottom of which is covered with sand, or fine coke dust, to the depth of about 3 centimetres. Drawn to the spot where the bricks are to be made, the slag and sand are mixed together with a curved iron tool, until most of the gases have escaped, and the mass assumes the consistency of dough. By the application of the same tool it is then drawn into a mould with a hinged cover, and punctured several times, to enable the remaining gas to escape. From this point the *rationale* of the manufacture as carried on in Silesia corresponds with that now being attemped in the Cleveland district. Slag bricks in Silesia cost 25 per cent. less than ordinary bricks, and as they do not

readily absorb moisture they are largely used in the construction of foundations.

Our readers may be interested in knowing that Mr. Thos. Greener, of Darlington, is chairman of the new Tees Scoriæ Brick Company, and that any further information as to the process of manufacture, or other collateral particulars, may be obtained either from him or from Mr. Woodward, the patentee.

THE OFFENSIVE USE OF TORPEDOES IN NAVAL ACTIONS.

From "The Engineer."

One of the most perplexing, and yet interesting studies which will fall to the lot of the military historian of the nineteenth century, will be that of the introduction, development, and frequently the disappearance of the many wonderful engines of warfare which the mechanical activity of the present day gives birth to. Of none, perhaps, has the rise been so sudden, and the sensation it has created so wide-spread, as the attempt to devise a system of torpedo warfare, and especially to use electricity for this purpose. This subject has held its own longer than any other, and received a far greater attention than it really deserves, from the fact that a profound mystery has from the first been associated with the whole art; and the greatest pains have been taken by the different Governments to prevent the results of their experiments, and their schemes for applying them, being generally known. We venture to assert that the high importance which has been attached to this question is an entirely fictitious one, and that the time has come when we are entitled to ask the enthusiastic advocates of torpedo warfare for the scheme which years of experiment should have elaborated. We fear that even the warmest advocates of these weapons are beginning to feel that they have yielded too readily to the seductions of a new and most attractive science. We may well believe that the father of the art—Fulton—met with insufficient appreciation at the hands of the unscientific sailors of Nelson's time; but we question whether their practical and keen insight into the merits of the case does not compare well with the inconsiderate haste with which, notwithstanding the wide-spread mechanical knowledge of the present day, the total reconstruction of our navy has from time to time been advocated by some of our leading journals, such avowedly being based upon a consideration of insufficient and generally over-estimated experiments with some new engine of destruction.

It may be interesting briefly to glance through the torpedo question as it affects offensive naval warfare, and to show what, in our opinion, is its present position. Without entering into the details of the numberless projects invented of late, which would occupy far too much time, we will rapidly examine three principal systems of offensive torpedoes, or torpedo vessels. These are:—First, torpedoes carried by vessels specially constructed for this service, which are capable of being launched in a fixed direction, and of preserving it under water, thus striking an enemy at a certain distance. This is known as the Whitehead system. The torpedo vessel carries a horizontal tube, usually in the bow and in a line with the keel, at a depth of about 8 ft. below the surface. The torpedo is projected and worked by compressed air, and attains a speed of from six to seven knots, preserving a constant depth below the surface. As the apparatus proceeds its speed decreases, owing to a diminution in the expansive force of the compressed air; nevertheless, we may estimate its average speed at six knots. At the moment of launching it is necessary to reduce the speed of the torpedo vessel so that it shall be a knot or a knot and a half inferior to that of the torpedo. This precaution is essential to avoid accident. The necessary slackening of speed is one of the inconveniences inherent to the Whitehead system, and one which may bring about the most serious consequences to the attacking ship. It is easy to comprehend the danger of slackening speed just when within reach of an alarmed and ready adversary. On the other hand, as the torpedo has to be projected towards a moving object, it is not difficult to see that uncertainty of result increases rapidly with the distance of the vessel attacked. To achieve success, the torpedo vessel must take into consideration the course of the vessel attacked, must accurately estimate her speed, and must then manœuvre so as to place her bow at a

projecting angle very difficult to determine with such problematical data. It is not necessary to dwell upon the details of the Whitehead torpedo; from the slight sketch we have given, the extreme importance of skilful handling of the torpedo vessel will be appreciated. She should endeavor to approach as near as possible, and, taking into consideration the speed and course of the enemy, project the torpedo so as to strike her bilge, then make off as fast as possible and prepare a fresh attack. The tube or cannon which projects the torpedo being placed in a line with the keel, it follows that the captain must, by a suitable manœuvre, place the bow of his vessel so that the direction of her keel passes a certain distance ahead of the enemy, in order that the torpedo, by its own velocity, may arrive at the point where the two courses meet at the same instant as the vessel attacked. Sailors know the difficulties attending the attempt to ram an adversary; they ought to be able to tell us whether any practical result can be arrived at in estimating by the eye alone the course, distance, and speed of a moving target. However seductive this system of torpedoes may appear in theory, we are forced to the conclusion that it in no way strengthens the attack in the open sea on an enemy who is master of his movements. Looking to the result of a long series of experiments by the Torpedo Committee, that at a distance of about 300 yards a torpedo projected from a vessel at rest against another vessel at rest in still water or a moderate tideway, has a fair chance of striking her, we are confirmed in the opinion we have all along held, viz., that the Whitehead system is not applicable to naval actions on the high seas, however successfully it may be used for the defence of ports or the attack of ships which commit the grave imprudence of remaining at anchor on an enemy's coast.

The second system is that of carrying torpedoes fixed at the extremity of spars projecting from the bow of a ship, sometimes above and sometimes below the water (a system much used by the Americans during the war, and since then largely developed by them), depends, as a rule, for success on the power the attacking ship has of concealing her movements, whether by fog, darkness, or other causes, so as to take her adversary by surprise. For this purpose small vessels, presenting but little surface above water, have generally been used; nor have the insuperable difficulties and dangers of submarine boats entirely prevented their application to this purpose by desperate and determined men, at the same time their employment has necessarily been limited to calm waters and the vicinity of a port. The impossibility, notwithstanding great efforts and many experiments, of employing so delicate an agent as electricity in the explosion of these torpedoes, and the extreme danger in the confusion of a sea-fight of using mechanical or self-acting exploders, have prevented the application of this system to large ships. Hence we may say that this system also is inapplicable to actions on the high seas.

The last system, of which Captain Harvey's torpedo may be considered a representative, is that of towing torpedoes. In this system two torpedoes are towed, one on each quarter, at a lateral distance of about 50 yds. from the vessel's track. They remain at the surface until shortly before striking, when, by slackening the towing line, the torpedo is dipped under the enemy's bottom and explodes upon contact.

The advantage of this system over the others is, that the torpedo can be towed for defensive purposes from almost any vessel, and that it then adds largely to security against being rammed. The attack can be delivered in several different ways: (1) both ships holding the same course; this argues a great superiority in speed on the part of the torpedo vessel. (2) The ships steering directly opposite courses; this supposes the enemy to be surprised or incapable of defence. (3) Crossing either ahead or astern, a condition into which the two previous methods will most frequently resolve themselves. To cross an enemy's path and pass close ahead of him, not only demands superiority of speed, but also there must be plenty of room for manœuvring with safety, and for steering with the greatest precision in order to avoid being struck by the enemy's ram. We see that this is a very hazardous manœuvre, and one which ought only to be resorted to under exceptionably favorable circumstances; but it is the only one which torpedo vessels of equal or inferior speed can attempt with a chance of success.

If, on the other hand, the torpedo vessel passes under the stern, she must immediately turn in the direction of the ship attacked, and, using the superiority of speed, which

is necessary for this manœuvre, draw slowly along the broadside of the enemy in order to insure contact. It is needless to dwell upon the danger of being thus exposed, at a distance of fifty yards, to the whole weight of a heavy broadside fire in a small and lightly-constructed ship. Success would be only too surely followed by the almost immediately sinking of the victor. The danger of carrying these destructive weapons exposed on a vessel's flank for a chance shot to explode, and the great care necessary in launching them, etc., have led to the proposal to explode them by electricity; but, as we before remarked, this agent is unsuited for naval purposes, and no success has attended the attempt. As a great superiority of speed is necessary for these torpedoes when used offensively, the construction of special ships has been deemed necessary. Looking at the difficulties which attend the employment of this system on a large scale, we may, without denying the success which has attended certain experiments with them, refuse to be led away by the illusions of inventors.

In conclusion, we may say that the introduction of these new weapons tends to neutralize the offensive power of each, and renders caution more necessary; the ram will demand it from the torpedo, and *vice versa*. Perhaps the tendency of all will be to replace guns and gunnery in their old position, and to restore the pre-eminence of pluck and endurance. Though we hesitate to accept any of these systems as satisfactory for offensive purposes, we fully recognize the important part which torpedoes may play in coast defence. The large sums spent, and the many experiments made both at home and abroad, bear witness to the importance of the question. Complaint has been made that our naval establishment compares badly in this respect with those of foreign Governments; but it should not be forgotten that in America, France, and Germany, the naval budget bears the expense of this Department, the large sum allotted this year in Germany being required for the maintenance of the whole Torpedo Department. With us this service is kept in the hands of the Royal Engineers, and looking to the conclusions we have arrived at, when considering the offensive or naval side of the question, we think the arrangement a wise one.

ON THE APPLICATION OF ARCHITECTURAL DESIGN TO ENGINEERING WORKS.*

From the "Building News."

Architecture is artistic construction, or, in other words, graceful and decorated building. Grace embodied in the structural contrivance, and grace superadded, were necessary in the form and ornamentation. The enjoyment of art was therefore nothing more than the perception and appreciation of the effort made by the designer to please by means of the introduction of the element of grace. It was therefore obvious that the building work of the engineer should be, equally with that of the architect, the legitimate subject of graceful design, *i. e.*, of art. There would so far, indeed, be absolutely no difference between the engineer and the architect, the distinction between those two classes of building designers being only one of convenience in the division of labor, whereby the architect devoted himself more to ordinary house-building, and all that was connected therewith, and the engineer took up the more simple and massive order of undertakings, such, for instance, as bridges and quay-walls (leaving out of the present question such works as canals, harbors, and railways), and those collateral works which, although pertaining primarily to the architect's province, had been recently carried to an unusual pitch of advanced mechanical contrivance, such as the great roofs. But there was no reason why engineers' work should be ugly, as was sometimes thought it must be, because it was taken out of the hands of the architect for convenience. Not only should it be not positively ugly, but it should be rendered positively graceful. To this end it would not be enough merely to take the ordinary details of architectural design, and apply them, somehow or nohow, to the engineer's work. The Professor said he was old enough to remember when a book was to be had which treated of the

* Abstract of a paper read before the Civil and Mechanical Engineers' Society, by Prof. W. C. Kerr.

application of the Five Orders of Architecture to the steam-engine, so that one could have an engine of the Doric, Ionic, or other style, according as his so-called "taste" dictated. This, however, was radically unsound in principle, because the subject so treated was one of mechanical engineering, and therefore out of the architect's range altogether. But, in like manner, the mere attachment of columns and a bit of entablature, or of the corresponding features of Gothic work, to the piers of a bridge, was little less objectionable, because the treatment was a sham as regarded the proper purposes of the architectural work so applied. Above all things in engineering, there should be no shams; the existence of the construction, in all its articulation, was essential, and the art of the matter must be inflexibly based upon the fundamental condition, that it was to be involved in the science of structural contrivance—admitting, in fact, of no modification thereof except the minimum of necessity to meet the requirements of grace as a subsidiary element in the contrivance. Much had been said about a new style, as if it only required a sufficiently intelligent effort of will to invent an entirely novel method at request; but nothing of this sort could be achieved in any art, and in architecture particularly it required the concurrent influences of a variety of essential purposes to produce anything really new. Herein consisted the chief advantage of the proposal that engineering should be made artistic, for in engineering we had new purposes. The objects of the work were frequently altogether different from those of past architectural effort; the materials, either in themselves or in their application, were often different, and the manner of conducting the scientific design, if not new in mechanical principle, was in many kinds of work quite novel in administration. This it was which more than any other consideration encouraged the lecturer to press upon the engineering profession the necessity for rendering engineering works artistic. He said he proposed to divide his subject under four heads: (1.) Wall-work. (2.) Arch-work, (3.) Iron Truss-work, and (4.) Iron Girder-work. These four divisions would include almost, if not quite, all the varieties of construction and design which needed to be looked upon as being essentially involved in the subject. With regard to the first division, Wall-work, there was less to be said than in the case of the other divisions. It might be further suggested that in this particular matter the resources of architecture were exhausted. For three thousand years, to our certain knowledge, men had been continously working at the more or less artistic designing of wall-work. It was perhaps the first and foremost of the subjects of ordinary architecture, and taking into view the wall-work of the Egyptians, that of the Greeks and Romans, that of the various schools of the Mediæval period—Byzantine, Romanesque, Gothic, and Saracenic—with all that had been done in the present or modern European era, there seemed to him no field in which the engineer could hope to introduce much originality. At the same time, as regarded that novelty of purpose which was spoken of as the essence of artistic treatment, he felt that even in wall-work there was a peculiar majesty and great massiveness in certain engineering projects, which, if fairly taken up in the artistic spirit, might produce an interesting character, equivalent to novelty in a certain sense. And here probably the Egyptian type of treatment would be found the most suggestive, owing to its great simplicity and its Herculean characteristics of detail. [The Professor here illustrated on the blackboard the mode in which the Egyptians disposed their typical wall, with a batter on the face, and a plainly-covered crowning course or cornice, and no stylobate, comparing this with the Greek mode of treating perpendicular faces with stylobate and entablature.] As examples of architectural wall-work taking the place of what too many engineers and others at the present day would make crude plain stone or brick facing, the lecturer showed the mode of treatment adopted in the Roman Coliseum, the Bank of England, and Newgate Gaol, and pointed out the application of artistic principles therein visible. The lecturer concluded his remarks on this section of his subject by suggesting that sculpture on a colossal scale, probably in *basso relievo*, might be attempted with great promise. If he had a vast expanse of naked wall to deal with, nothing would delight him more than to hand it over to the sculptor, with directions to trace thereon the outlines of some stupendous figure-work, and then simply go to work and cut it in low relief, like that of the Egyptians, to stand before the multitude in its sheer vastness and simplicity. Turning to the

second section of his subject, viz., Arch-work, the Professor said he felt bound to acknowldge that it was in Mediæval architecture that arcuation was carried out to perfection. At the same time it should not be forgotten that the Romans had previously introduced the mode, and had pursued it with great success, both structurally and artistically, as shown, for instance, in the Coliseum *façade* before referred to. Speaking to engineers, he knew they would understand him when he pointed out that the pointed arch was essentially stronger than the semi-circular form. Still, Mediæval building, with all its wonderful and elaborate system of counterpoise, was but crudely designed as regarded what we should call science—in other words, Mediæval science was in such a backward state that few, except archæologists, would recognize it as science at all. Gothic work, in short, was done very much by rule of thumb—arrived at tentatively; and a great many churches which were not strong enough to stand had disappeared. Those Gothic buildings which existed at the present day were merely those which happened to be better built than others which had fallen. The Mediæval men, for instance, knew nothing whatever of the truss. But the excessive lightness of their arch-work was most remarkable. This characteristic of complete lightness, however, was obviously a step in the opposite direction to the simple majestic repose which seemed so essential to the idea of engineering arch-work rendered artistic. At the present day, unfortunately, Gothic work—more particularly as practised in secular buildings—was too often rendered ugly of *malice prepense;* it was intentionally ugly, for the sake of violating what were considered to be the effeminate rules of the Neo-Classic mode. The "muscular Christians" of the modern Gothic school sought to cure this effeminacy by showing the world how masculinely ugly they could make their buildings. If the engineer's work was to be ugly, let it be ugly, because he could not make it present a better appearance. One characteristic difference between Gothic and Classic was one which engineers would readily appreciate—namely, the difference between the merely picturesque and the architecturesque. The latter word was a pet phrase of the lecturer's own, but he maintained that it had a meaning which could not be expressed by any other term. "Picturesque" was the character of being picture-like, and "architecturesque" was the character of being architecture-like. If engineers wanted to make their work picture-like, he had nothing to say against their adoption of the Gothic style; but if they wanted to make their work architecturesque, they would not, in his opinion, adopt that style. Mediæval work was picturesque or nothing. On the other hand, Classic buildings—such as the Bank of England, the Royal Exchange, and Somerset House—were characterized by architecturesqueness, possessing a character of repose which was totally independent of picturesqueness, and which could scarcely exist in common with it. It would, he thought, be suicidal for engineers to fix their attention upon the Gothic style of the present moment as the *point de depart* for rendering their works artistic. If their works were to exhibit any real feeling for art, they must develop a new style of their own, suited to the special circumstances of their work; and he ventured to say that for the basis of such a style, engineers must look to Neo-Classic work (or, in other words, to the Modern European style of architecture) as their type. It was from the comparatively solemn, muscular, majestic work of the Classic type that engineers must expect such a development as would suit the circumstances of their works. With regard to arch-work particularly, one thing that had never been done in architecture, but which it was open for engineers to do, was the equilibration of the arch. Increasing the depth of the voussoirs from the haunches to the crown of the arch was clearly not the thing, and where it was done, it was obviously nothing in the world but a mere piece of show, manifestly unscientific. There was no reason whatever why engineers should not equilibrate their arches, and show it honestly; and particularly, there was no reason why they should not treat in the most artistic way their bridges upon the very basis of the equilibration of the arch. Coming, thirdly, to the question of iron roofs and trussed work, the Professor remarked that this was ground more peculiarly modern. Such a thing as a truss was unknown in the middle ages. In Mediæval work, the tie-beam, strange as it might appear, was always a beam. It was never in tension, but was always subjected to cross strain. The king-post also in those times was a post, and was in compression, not tension. Nothing could be more remote

from trussing than that system; and nothing in mediæval carpentry was much better than that. The great arched ribs of the middle ages derived their strength from being pinned together in the manner of our own semicircular ribs. The idea of trussing, like all other good things which belonged to modern European enterprise, was discovered in Italy in the sixteenth century. He was glad he was speaking to engineers, for architects would not believe this; they were too often lost in the whims and fancies of mere archæology. The truss, then, was the product of the Classic, or rather Neo-Classic period, *i. e.*, the period of the fifteenth and sixteenth centuries, because Italy of that period was the cradle of our age in architecture as in all other things. Of course we had made immense strides in construction from the primitive truss of the sixteenth century in Italy to the wide-spanned spider web-like roofs with which we were now so familiar at our railway stations and elsewhere. The introduction of rolled iron had been not only the making of England as regarded railways, but it had been the making of engineers as regarded trussing, allowing them to introduce scientific construction to the utmost limit. It was a curious fact that trussed roofs had never been thoroughly architecturally treated, and the reason of this might be profitably inquired into. He did not know, for instance, of any ordinary roof truss which had been artistically treated in itself, showing the articulation of its construction honestly, and yet presenting elegance of appearance throughout all its parts. Suppose the architect were to set himself the task of rendering the truss architectural, the first consideration was that the conditions of the most absolute science should not be sacrificed to design. Art was not to supersede science, nor was it opposed to science. Art was merely something which was introduced as an element of pleasure, incorporated with and not merely super-added to science, its introduction modifying the forms of science a little, although very little—only just sufficiently indeed to secure the maximum of artistic effect with the maximum of scientific strength. In treating a truss artistically, therefore, it was necessary, in the first place, to design it in strict accordance with the necessities of scientific construction. Art should be introduced into it only in such a way as to suit certain modifications of the scientific forms, always remembering that it was better in works of that kind to sacrifice art to science than science to art, although in the generality of cases the two might go hand-in-hand, without the necessity of sacrificing either. Taking next the case of road bridges, the Professor said he supposed the day had gone by for making such bridges with cast-iron ribs. But in the case of a built-up iron girder in the form of the arch, how ought it to be treated? To take the beams divided into the proper number of lengths in imitation of stonework, and so connect them, was not art. The circular form had, in reality, nothing to do with the theory of such an arch. The circular form of the arch was that in which it became ultimately developed in stone, provided certain conditions were fulfilled, and not otherwise. It was a great mistake, therefore, to set out an iron road-bridge on the segment of a circle and there leave it. The intrados of each beam ought scientifically to be straight or convex, and why then should it be made concave? It was utterly wrong in principle to take the mere form of the stone arch as the model for an iron bridge. A stone bridge assumed the circular form merely because the voussoirs were so short that it was not worth while to make them straight at the intrados. With regard to suspension bridges, Professor Kerr said he did not think that anything like the principles of architectural design could be applied to them, because they were obviously more of the nature of mechanical engineering works than of what he might term architectural engineering works. It was of course true that the piers might be rendered architectural features, and the roadway might be treated to some extent on architectural principles, but he did not see how it was possible to treat the chains architecturally; it was obvious, indeed, that no architectural principles could be applied to chains. With reference to the great iron roofs of which so many examples were now to be seen, the Professor said that if there was any one description of engineering work which ought to be rendered artistic, it was these great railway station roofs. There was no reason in the world why such structures should not be rendered elegant and graceful in the extreme, inasmuch as they possessed primarily in themselves all the elements of gracefulness, impressiveness of outline, and grandeur of form; and it would be possible

to introduce something at any rate, of an artistic nature, without materially adding to the cost. Excepting at the Great Western Station, Paddington, scarcely anything had been done in that direction. He considered Mr. Barlow's roof at St. Pancras Station to be in itself one of the most elegant roofs he had ever seen; still, no attempt had been made to introduce art into the work. He did not blame engineers because they did not introduce art into all their works, for, like architects, they had to abide by their instructions, but he thought that they might often do better if they knew how, as of course they generally had unlimited funds to deal with. (Laughter.) In endeavoring to render such roofs as he had referred to artistic, the articulation of the construction should always be left apparent. If the construction were concealed, the chief element of proper building art was destroyed, and the domain of sham was entered; and when once shams were resorted to, it was impossible to tell where their employment would end. He could not but reiterate most emphatically that the first great rule was to exhibit the science honestly and faithfully, however much they adorned it, and to be by no means ashamed of true construction. In trussed work it seemed to him that there were two new elements quite capable of being made the basis of new means of architectural design. Firstly, there was the rodwork, comprising the slender iron tie-rod performing the duty formerly undertaken by the cumbrous tie-beam, and the king and queen rods, fulfilling the duties of the old king and queen posts. At the same time, within such limits as those to which it was usually applied, it introduced a new element which must be treated on new ground. No architectural ornament would do for a rod, unless it was something derived from the brass pipes with which candelabra were suspended, the application of this kind of treatment being quite out of the question for the rods of our great iron roofs. Rolled sections of iron, again, were a novelty in construction, and any application of art to them must be on an entirely new basis. Indeed, the invention of a new style of construction—a method suited to new materials and conditions—was a problem really in the hands of engineers. The Crystal Palace might be said to have introduced, almost by accident, an entirely new mode of wall construction—an iron framework filled in with glass—a method of construction which was capable of being developed into something extremely graceful and beautiful. The worst feature, artistically, of the generality of that class of work was the arcading, not but that the *ensemble* of the arcade was exceedingly good, but it was not the result of constructive necessity, and why should the form of the arch be introduced in such work merely for the sake of customary outlines? Such an appropriation of forms was not art. The Crystal Palace style of work properly consisted of uprights, cross-bearers, and brackets to shorten the bearings between the uprights. Why, then, should not the Crystal Palace arches be made brackets in outward appearance as well as in constructive reality? This Crystal Palace work was an apt illustration of the danger of introducing architectural forms into the ironwork of engineers' structures; although it was questionable whether the results would have been surpassed, or even equalled, had an architect been the designer. With regard, lastly, to girder work, it should be remembered that a built girder of plate-iron was comparatively a constructive novelty, although it had been in use long enough to make it discreditable to architects and engineers that no attempt had been made to render it ornamental. He remembered some girders of this kind which he himself had put in about twenty years ago at the offices of the National Provident Institution, in Gracechurch street, which he thought afforded satisfactory evidence that plate girders could be ornamentally treated in architecture; but very few attempts had been made in this direction since. It was very easy to attempt art in this way, and yet to pay due regard to all the requirements of constructive science. Here, again, he would repeat (for it could not be too often reiterated), that it was necessary, first, to design any work of engineering in strict accord with the absolute necessities of science; and then the same work might be re-designed, so to speak, on another sheet of paper, retaining all the essential constructive features, and modifying the forms only so far as would be necessary to render the constructive perfection agreeable to the eye. In a plate-iron girder the work of the structure was performed by the flanges, the web doing nothing more than to hold the top and bottom flanges at a certain distance apart. The diagonal

braces of a lattice girder fulfilled the same office, and the work, therefore, might be open or pierced, because there was no need for the web to be solid. Why, then, should not the webs of plate girders be pierced in varied patterns, or *guillocles*. A web pierced in this manner would serve all the purposes of a solid web, and would present a very pleasing appearance. It was difficult to account for the thing not having been more generally done, especially as the extra cost would not be great. As to the flanges, they were very generally put together and rivetted in an exceedingly rough, not to say unworkmanlike manner. A little more finish and neatness in the workmanship would vastly improve the appearance of plate girders. Every rivet might be made ornamental. In the girders before referred to, the Professor said he had caused a little patera to be screwed on to the head of every rivet, and these, being gilt, presented a very good effect. A box girder might be ornamentally treated by attaching light iron castings or wrought-iron scroll-work on the outside of the webs. Lattice girders, which were now so largely used, were capable of being rendered particularly artistic, and something more pleasing than the ever-recurring diamonding on a huge scale ought to have been done before now. At a glance, it seemed to him that if architecture were applied to lattice-work, very little trouble and expense would suffice to make lattice girders most beautiful objects in detail, instead of being left, as at present, in all their nakedness; but it was of no use to stick on a few wretched castings, or to rest content with facing the abutments or piers with polished granite shafts. Tubular work was the last he should mention, inasmuch as it presented a comparatively restricted field for anything like treatment on architectural principles, although it had produced objects most imposing in their character, and was possibly destined to produce still more majestic and magnificent structures. Of course, outline was the important consideration in such works as these, and what ornamentation was used should be simple and grand. But why should an ordinary railway viaduct crossing a street be so intolerably ugly—almost intentionally ugly—as was usually the case? Such structures as he was referring to, the engineer might surmount with a cornice—not an architect's cornice, but an engineer's cornice (a thing yet to be invented)—and below he might have his sill moulding—also yet to be devised. Between these he might fill in with good bold ornament in relief, and so render the structure beautiful. In this connection the sculptor might advantageously assist the engineer by modelling relievos, to be cast in metal, or even hammered out. A few figure-subjects might be so used with marvellous effect. In conclusion, Professor Kerr again enforced the necessity of designing artistic engineering work in the right and only way. He would first design the work on one sheet of paper as at present, with regard solely to the necessities of scientific construction. These requirements fulfilled as it were in the skeleton, their constructively-perfect forms should be translated, so to speak, into what would be essentially the same forms slightly modified to suit æsthetic requirements. The ornament should not be designed first, and the construction suited to the ornament, nor should the construction be merely clothed with ornament afterwards; the only true way was to make the ornamental element an integral portion of the whole design, which could only be done in the way he had indicated. The ornament should never hide the articulation of the structure, but the construction should always be honestly and fearlessly shown, elaborated to any extent in artistic grace, but never compromised in its essentials. This would be true engineering art, and the sooner it was fairly tried the better.

The "Slatington News," in referring to the Berks County Railroad, says: This road, as we have heretofore said, will be of great benefit to our slate shippers as it will open a new and short route to the West for shipment of slate without change of cars. As a passenger road it will have the traffic of all the country from above and around this place, that goes to Reading, and westward by that route, as it is twelve miles nearer than by way of Allentown. The local traffic will also be of considerable importance, and the coal trade of the Lehigh Valley Railroad, and the New Jersey Central, which it will unite with at this place, added to the shipment of slate, iron, farm products, etc., will, we believe, make the Berks County Railroad one of the best paying roads in the State.

THE RESULTS OF RECENT METEOROLOGICAL INQUIRY.*

From the "Nautical Magazine."

Of all the branches of science there is not one which so entirely depends on the conjoint and harmonious co-operation of numerous observers as Meteorology. If we are to compare it with its nearest congener, Astronomy, we see that, while in the latter case, the range of subjects which an isolated observer can study, when there are no clouds, with a prospect of doing good work, is only bounded by the extent of sky visible to him in the course of the year; in the former, the phenomena which can come under the cognizance of the most enthusiastic meteorologist are strictly limited by the geographical position and the local conditions of his station, as to its elevation above the sea, as to the condition of the surrounding country, and even as to the very nature of the soil itself.

It is therefore self-evident that if by any means meteorologists, all over the globe, can be brought into personal relations with each other, important advantages in the prosecution of the science may be looked for, and the main tendency of our endeavors of late years has been towards the cementing of these ties of mutual co-operation and helpfulness.

This most desirable result has been greatly furthered by the several meetings and congresses of meteorologists which have been held at various times. I am glad to say that the commencement was made in this country, mainly at the instigation of Sir E. Sabine, at the meeting of the British Association at Cambridge, in 1845. Then followed the Congress at Brussels, in 1853, which dealt solely with marine meteorology; the credit of this assemblage is almost solely due to the indefatigable energy of Maury, whose recent death we are now deploring. From this Congress the systematic prosecution of Ocean Meteorology may be said to have taken its rise, and as it gave such a vigorous impulse to general meteorological inquiries, and prepared the way for the establishment of meteorological organizations, under the auspices of the respective governments of the civilized world, it will be convenient for us to take our point of departure, for discussing the results of recent meteorological inquiry, from 1853. At the present time, it is in contemplation to hold a Meteorological Congress at Vienna, in the course of this year, of which the aim is the more perfect organization of combined operations in the study of meteorology on land.

A Conference, preliminary to the Congress, was held at Leipzig, last August, which was well attended, but it was chiefly deliberative, in order to define the subjects to be discussed at the General International Congress.

If I were to characterize, in a few words, the general results of our inquiries since 1853, I should say that if we except the development of meteorological telegraphy, which dates from about the year 1854, in France, we must admit that these results have not been marked by many startling discoveries, comparable with those effected in astronomy by the aid of the spectroscope, but are to be sought for principally in the correction and completion of the data on which the theories of former times were based, by means of more perfect instruments and improved methods of observing with them; and in the turning to practical account, for seamen in the first instance, and in a less degree for agriculturists, also, the conclusions to which the scientific study of the subject has led.

As an example of the former class of work, the correction of received theories, I may cite the recent investigation into ocean temperatures at great depths, which has modified all our ideas of marine circulation. This inquiry has been carried out during the successive cruises of the Lightning, the Porcupine, and the Shearwater, and is now being prosecuted on a scale of true magnificence by Professor Wyville Thomson, in the Callenger, thanks to the wise liberality of our Government.

A brilliant instance of results of the latter kind, the utilization of theoretical meteorology, is found in the well-known statement of Maury, that the average passage from both Europe and the United States to San Francisco was shortened from 180 days to 135 by the researches as to winds and currents which were conducted under his superintendence at the Naval Observatory at Washington. In speaking thus, I must

* A Lecture delivered at the London Institution, by Robert H. Scott, M. A., F. R. S., Director of the Meteorological Office.

not be understood to underrate our work, or to imply that its results have been either insignificant in quantity or unimportant in quality. I only mean to convey to you that, owing to the extreme complexity of their subject, meteorologists have not of late years arrived at any grand generalizations which have been at once accepted as incontestable.

It will perhaps be of interest to you, if, before taking up the subject of weather telegraphy, I proceed to point out the progress which has been made in the chief branches of our science since 1853.

Temperature will naturally come first, as its influence on climate, and on all the processes of organic life, is more immediate than that of any other meteorological element, and as, fortunately, our knowledge of its distribution over the earth's surface is, comparatively speaking, in a satisfactory state, it will give you a good idea of our present views on this distribution in a general way, if I explain to you the two isabnormal charts for January and July, which I have exhibited. The principle on which these charts have been constructed is, that as the temperature of the earth ought, theoretically, to decrease regularly from the equator to the poles, and as we find that these conditions are not nearly fulfilled in reality, it is of interest to show how much the temperature in each region of the globe has been ascertained to hang on one side or the other of its theoretical mean value. The charts are called isabnormal, as they show the lines of equal difference between the actual and normal temperatures.

Having thus seen what we know of the general temperature of the earth, it will be of more special interest to us to consider what we know of the temperature of our own islands. Mr. Buchan, of Edinburgh, of whose name there will be mention more than once in this lecture, has published an important paper on this subject, based chiefly on the returns issued by the Registrars General for England and Scotland.

It must not be forgotten that Temperature, taken by itself, is not sufficient to account for the differences of climate which are found even over the limited area of the United Kingdom, and that we must take into consideration, along with the readings of the thermometer, the conditions of wind, rain, and cloud, etc.; but yet isothermal charts will give a fair general idea of the broad features of the climate of the country. I have, therefore, prepared two charts showing the course of these curves for the months of January and July. (These have been already described in the "Nautical Magazine" for 1872, p. 570.)

Recent results in respect of Atmospherical Pressure have been more striking than those first described in regard of Temperature; and here again we have to give the main credit to Mr. Buchan. It has long been known that the mean barometrical pressure at sea level is not the same all over the globe, as the remarkably low readings obtained near Cape Horn, and the uniformly high level of the mercury near the Tropic of Cancer, over the Atlantic, had attracted the attention of all. Mr. Buchan has earned the thanks of all meteorologists by having faced the enormous labor of determining the mean pressure for a large number of stations (360 in all), from which he has been able to draw monthly and annual isobaric charts. I produce the chart for the year, which is very remarkable, and, as we shall see later on, enables us to draw important conclusions as to probable winds.

It is, however, in connection with the wind that the most valuable additions to our knowledge have been made. You will all have heard of Reid and Redfield's Law of Storms, which is to the effect that the hurricanes of the West Indies and the Indian Ocean are storms in which the wind blows round a central area where the barometer is comparatively very low; and that the direction of its motion in the Northern Hemisphere is opposite to that of the hands of a watch. Prof. Buys Ballot, of Utrecht, has extended this rule to all winds, and has laid down a principle whish generally goes by the name of his Law. It runs thus:—"Stand with your back to the wind, and the barometer will be lower on your left hand than on your right."

This law shows us that the old idea that the direction of the wind is governed by the absolute height of the barometer at the place must be abandoned, and that, instead thereof, we must look to the difference between the heights of the barometer at adjacent stations in order to learn what the motion of the air will be. When we come to speak of weather, we shall see the all-important bearing of the considerations I have just described.

The winds have been a favorite subject of study with all meteorologists, and the

arguments for and against Maury's theories were for a long time the theme of many a discussion. We may say that nowadays his theories have been entirely abandoned, as no one at the present time believes in the complex system of interlacing currents which was propounded by the Naval Observatory of Washington. It has been found that Buys Ballot's Law holds good for the grand atmospheric currents, as well as for isolated wind observations, and so the chart which I have shown you exhibits not only pressure, but also wind, in its broad general features.

The most important work of our office, and that to which it owes its original establishment, has been pre-eminently the study of the winds. This inquiry is most diligently pursued by the Marine Department under my colleague, Capt. Toynbee, and as a specimen of the character of the results we are obtaining for the Mid-Atlantic for a small district of 10 deg. of latitude and longitude, which is, however, the most important patch over the whole ocean, as regards making a passage to India or Australia, we find that in certain months of the year a navigator may find a route by following which he will sail through the square in seven or eight days, whereas if he keeps to the route, which is still adopted by many captains, he will probably have to spend thirteen or fourteen days in making the same distance good.

As regards rain, which has been studied most carefully for these islands by Mr. Symons, by means of the corps of observers which he has organized, the general tendency of discovery has been to show that the empirical rules so often laid down by engineers as to the variation in the amount of rain which falls, with height above sea level and distance from the coast, are of purely local value, and that, in order to draw conclusions as to the probable amount of water to be obtained from any district for economic purposes, we must consider the general contour of the country about, and more especially the lie and height of all the hills and mountains in the neighborhood.

Before we quit the subject of general meteorology, it may be of interest to you to hear what has been done of late years in the way of enabling us to foretell the character of the seasons. One great difficulty which meets us at the outset is that we do not possess accurate meteorological records for more than about 20 or 30 years from any considerable number of stations, and so we are not in a position to say with certainty whether or not a certain character of the seasons has shown a tendency to recur after the expiration of any considerable number of years.

In default of direct meteorological evidence, it has often been attempted to take the price of corn in England as a test of the character of the seasons. Such discussions have been conducted without regard to the fact that for the last thirty years the price of corn has depended on the foreign far more than on the home supply. All such reasoning is similar to the statement that earthquakes are on the increase of late years, because a notice of every shock in any part of the world appears in every newspaper.

The most probable period for us in which to expect a recurrence of seasons is at the expiration of 11 or 12 years, inasmuch as, 20 years ago, Sir E. Sabine proved that this period, the well-known sunspot period, is also reproduced in the phenomena of terrestrial magnetism. Moreover, there is every reason to expect that the connection between meteorology and terrestrial magnetism will ere long be established. Meanwhile, a direct connection between the cycles of weather over the Indian Ocean, and the intervals of frequency of sunspots, has apparently been discovered by Mr. Chas. Meldrum, of the Mauritius. He has found that the cyclones, which are especially frequent over that part of the Indian Ocean, have been much more frequent every 11 or 12 years than at other times, and that this frequency occurs when sunspots have been most abundant. A similar periodicity is exhibited by the rain fall returns from the stations in that part of the world, as has been shown both by Mr. Meldrum and Mr. Lockyer.

This discovery, then, affords us some hopes of at least being able to establish a connection between all the various phenomena which belong to terrestrial physics.

The study of the Non-Periodic Variations, or, in plain English, of the weather from day to day, has been the department of our science in which, more especially, we have signal progress to record. This has been almost entirely due to the facilities afforded for the construction of synchronous charts of weather by the extension of telegraphy. Isolated attempts to chart weather in the case of individual storms have been made

for a long time by Loomis, Dove, and others, as well as recently by Buchan, Mohn, and Hildebrandsson, but the idea of collecting and publishing daily an account of the weather over a large area of the earth's surface was first propounded in the United States before the war. The credit of first carrying out the plan in Europe belongs undoubtedly to Le Verrier, who first broached his plans about 1854, and on January 1, 1858, was publishing a daily bulletin of observations, to which he appended, on September 11, 1863, a chart, which at once attracted the attention of all who saw it. Admiral Fitz Roy commenced his reports in the newspapers in September, 1860, and these were first lithographed by us at the beginning of 1869. The issue of our present daily charts was commenced on the 1st of April, 1872, and their circulation at present exceeds 600 copies a day, of which about one-half go to subscribers, while one-half are supplied to Government offices, and for exhibition to sailors.

Russia, too, publishes a lithographed report, and in almost every country in Europe a daily account of the weather appears in the newspapers.

The telegraphic weather system of the United States is, beyond all comparison, the most perfect in existence. It is in connection with the Chief Signal Office at Washington, under the direction of General Myer, and these appear simultaneously in all the principal cities of the States. This is rendered possible by the fact that the telegraphic lines place their wires at the service of the department for a certain space of time every day; the splendid results attained are effected by utilizing the military organization of the country, and by a very liberal allowance of money. It is only fair to us to consider what the cost of this service is as compared with our own. The proportion of our annual vote spent on weather telegraphy is not more than £4,000, while the vote for the Signal Service is $250,000, or about £50,000.

Weather Telegraphy is intimately connected with storm-warnings, and so I may be permitted to say a word or two as to the history of this part of our duties in the office. M. Le Verrier, in a letter of April 4, 1860, proposed that telegraphic reports from all Europe should be sent to one central station (Paris), whence warnings should be issued to the points menaced, from time to time, by the storms, and in the course of the year, he applied for permission and funds to warn the coast of France. Admiral FitzRoy, in the same year, proposed to issue his warnings, which subsequently met with such general adoption; but, while this country and France were thinking about the matter, Professor Buys Ballot, in Holland, obtained leave of his Government, and commenced to issue telegraphic intelligence to the ports of Holland in June, 1860.

There is no need at this time to go over the history of storm-warnings in this country, and the changes which were made in this system on Admiral FitzRoy's death. Suffice it to say, that we only telegraph *facts*, and that we do not actually prophesy weather or storms, though of course our endeavor is to give such intelligence as shall enable the sailors who receive it to judge of coming weather. At the close of the lecture I shall say a few words as to the results which we are able to attain in practice.

The chart which I exhibit will show you our present system of reporting stations, with the exception of Christiansund, in Norway, and it will at once be seen from it how badly we are in want of information from the westward. While we are able to issue warnings of almost every storm which strikes the coasts of Holland and Denmark, we are frequently taken at unawares by storms on the exposed west coast of Ireland.

Various proposals have been made to surmount this difficulty; among them has been the idea of mooring ships off the coast, connected by telegraphic cables with the shore, and using them as floating observatories. The difficulty of carrying out this plan was proved by the failure of the experiment with H.M.S. Brisk at the entrance of the Channel. Lately, Mr. Morse, the famous telegraphist, has proposed to use buoys instead of ships, and to make them of such a size that habitable turrets could be built on them; but the idea seems hardly practicable.

The fact that the Azores lie out in the Atlantic, and that information from them would be valuable, has struck many persons, and the Portuguese Government has proposed to supply telegraphic reports from those islands as soon as they are connected by cable with the mainland. The Meteorological Committee have been requested to contribute towards the expense of this project, and they have at once consented to do

so, as the daily knowledge of the state of the weather in that part of the Atlantic cannot fail to be of service to us.

As regards the chance of our receiving early intelligence in this way of advancing storms it is very slight; the Azores are too far off for us to trust implicitly unsupported reports from thence, and even if the storms did travel from them to us they would undergo such changes, *en route*, that they would be hardly recognizable. There are strong grounds for asserting that they never do so travel, for we have compared the daily reports from the Azores with those from Valencia for nearly three years, and find no traceable connection between the storms which have been recorded at the two stations, and certainly no precedence in point of time for the Azores, as regards the barometrical changes.

We ourselves, for three years, received reports free from Heart's Content through the liberality of the Anglo-American Telegraph Company, but we found them of little service, partly owing to the distance, partly to the fact that the observations were necessarily uncorroborated, and partly because the wind reports were unsatisfactory, the station being badly exposed. Accordingly, when we were requested to pay for the reports, they were discontinued.

It has been repeatedly suggested that we should institute relations with the U. S. Signal Office, in order to get intelligence of advancing storms, and in December last a paragraph was copied into all the newspapers to the effect that the great annual November wave, which was so much talked about in this country ten years ago, had been recognized in North America, as travelling across the continent, and that therefore it was probably the cause of the storms which lasted for two months with us.

These statements are all based on imperfect knowledge. There is no doubt that many of our storms do travel nearly, if not entirely, across the Atlantic, though they have not come from the mainland of America. This was proved, for the storms of February, 1870, by a very careful examination into the weather of the Atlantic when the City of Boston was lost. The discussion was carried out by my colleauge, Captain Toynbee, and has been published by our office. According to it the storms seem to have been generated over the Gulf Stream outside the American coast, and not over the continent itself; for while the wind on the eastern edge of the Gulf Stream was constantly from the southward, that on the seaboard of the Eastern States was persistently northerly.

Inasmuch as we are thrown, to a great extent, on the resources of our own system for our knowledge of the weather, it is of interest to see what principles we have to guide us. If anyone looks at the plates in our Quarterly Weather Report, containing graphical representations of the curves of barometrical pressure, and of temperature as well as of wind force, he will see that it would be very unsafe to trust to the reports of any single station for gaining a knowledge of the probable force of wind. The barometer often falls rapidly without much wind being reported, and again when the wind rises to a gale the barometer frequently has given little warning of it.

In this case, Buys Ballot's Law, which I have already explained, is invaluable. The truth of this principle is admitted, implicitly, by many older writers; but the first definite statement of it, as applied to storms in these islands, as well as the first attempt to apply a numerical measure to storms, occurs in a work * by Mr. W. H. B. Webster (Surgeon, R. N.), in the following words—he is speaking of a comparison between the simultaneous readings of the barometer at Greenwich, and at Sandwich Manse, in the Orkneys:—"Whenever the barometer at Greenwich was higher than the barometer at Orkney, a southerly or south-west wind blew, the force or strength of the wind being in proportion to the difference between the two barometers." Dr. Webster then proceeds to lay down rules for the general relation of the wind to the barometer.

We do not know much of the precise relation of the wind to the barometrical *gradient*, or to the difference between the barometrical readings over a given distance; but it may be stated as a general principle that if this gradient amounts to 0.1 inch per 100 miles, there will be about as much wind as an ordinary small coaster will like.

I have already explained before that Buys Ballot's Law is only a development of Reid's Law of Storms, which is that the air moves round the centre of the storm in a direction

* "Recurring Monthly Periods and Periodic System of the Atmospheric Actions." London, 1857.

opposite to that of the hands of a watch, and that, at the centre, the barometer is lower than anywhere else; this direction of motion being reversed in the northern hemisphere.

As soon as meteorologists began to study the synoptic charts of the weather they found that the air sometimes moved in an opposite direction, *i. e., with* the hands of a watch, and that when it did so, the barometer over the district round which it swept was higher than elsewhere. These are, of course, simple deductions from the rule, but they have a most important bearing on the question of whether or not we can foretell weather.

The areas of low pressure with their circulation are termed *cyclonic*, while those of high pressure with their circulations receive the name of *anti-cyclonic*. On the mutual positions and motions of these areas all our weather depends, as the force of the wind depends on the gradients, and as there would seem to be, at first sight, no reason for these gradients being steeper in cyclones than in anti-cyclones, it would appear that we ought to have as much wind near the centre of an area of high pressure, as near that of an area of depression. This idea is quite incorrect, as we find that storms are almost always connected with cyclonic areas.

Our attention is consequently chiefly directed to these cyclonic areas, so as to ascertain as quickly as possible their size and shape, with the direction in which they are advancing, and the rate of their motion. Unfortunately, we are rarely able to know much on any of these points until the storm has burst on our coasts.

The two last particulars, the direction and rate of motion of storms over these islands, depend almost entirely on the distribution of pressure which exists when the disturbance arrives, and on the distribution of pressure depends the direction in which the gradients will be steepest, and consequently the direction of the strongest wind.

The cyclonic areas move much more rapidly than the anti-cyclonic areas, which hardly change their position at all, and the former appear never to advance into the latter, but to skirt round them. Thus, when pressure is high over France, we are liable to heavy westerly gales on the southern edge of cyclonic areas crossing England. When the highest pressure lies over the North Sea, the depression passes up along the west coast of Ireland, and we have southerly gales in Ireland, as at the end of January, 1870. When the area of high pressure lies over Ireland, we are exposed to a series of cyclonic disturbances passing down the North Sea, and bringing northerly gales to our east coast.

Not unfrequently we find the cyclonic areas slipping in between two anti-cyclones, and in this way many of our easterly storms are caused, the path of the centre of depression lying along the English channel, while the barometer is high in Scotland and in the south of France.

I have prepared a slide, exhibiting the atmospheric conditions on February 16, 1872, which will show you the co-existence of two cyclones and two anti-cyclones over the limited area covered by our reports.

On the whole, the best idea I can give you of the motion of our storms is, that they follow each other in the main current of air like eddies in a running stream, and sometimes we have more than one at a time over these islands. On Monday last we had three. The slide which I exhibit shows two: it represents the conditions of pressure on the 24th of January, 1872, when readings were so very low in London.

It would be impossible in this lecture to give you an idea of what we know of the origin and cause of storms, or of the mode in which we recognize the approach of a storm to our coasts; but it will be of interest to you to know that not very unfrequently we are visited by storms which travel so quickly that we have little hope of ever being able to issue warnings in time for them. Such was the storm of November 22, 1872, when the Royal Adelaide was lost, and that of February 10, 1871, of which I exhibit a diagram, will give you a fair idea of the changes which may take place within the short space of 14 hours, as apparently there were but few signs of a gale at 6 P. M. on the 9th of February, and yet at 8 A. M. next morning the storm was raging.

Lastly, we come to the actual practical results of our storm-warning system. In considering this, we must make allowances for cases such as those I have just cited, as well as for the regular weekly interruption of our work on Sundays, and though last not least, for the uncertainty caused by telegraphic errors. The Signal Office of the United States claims to have been right in 77 cases out of 100 in 1872, which is a very

good percentage, considering the conditions to which their service is subjected, which are in many respects far more advantageous than ours. We have been able to hoist the signals in time for the gales, in both 1870 and 1871, 46 times out of 100, and if we add to these about 20 per cent. for cases in which the hoisting of the drum was followed by strong winds, though not by a serious gale, we find in those years a total percentage of success of upwards of 60.

In the year 1872, as I am glad to say, the result is widely different. We have been in time for the gale in upwards of 60 cases out of 100, and as we have still nearly 20 per cent. for warnings justified by strong winds, we find a total percentage of success of nearly 80, which cannot but be admitted to be highly satisfactory.

I must not be considered as taking the entire credit of this result to ourselves; most of it is due to improved telegraphic facilities, which have rendered our work more certain and easy than was formerly the case.

THE STEAM-JACKET—ITS ACTION, ADVANTAGES AND DISADVANTAGES.

By A. HILDEBRANDT, C. E.

From "Iron."

This subject has had but scant justice done to it, on the whole, and still requires much attention and elucidation from the engineer to answer the query as to its economy. Nothing has been done towards settling the points at issue satisfactorily by means of carefully conducted experiments. It is a question that can be settled once for all; for with the present abnormal prices of fuel it behooves the engineer to bring it to a speedy issue.

As the object of the steam-jacket and the principle of its action are still imperfectly understood, by a great many, it is the purpose of this communication to describe and explain the appliance as briefly as possible, to consider its action, and to deduce such results as may fairly and justly be drawn from this consideration.

It would not be unpardonable if the young engineer supposed that the steam-jacket was a comparative novelty in modern steam engineering, judging from the wars that have raged of late on this subject. The "Jacket," however, is as old as the steam-engine itself, being the offspring of the illustrious James Watt.

The jacket consists of an annular casing, concentrically encircling the cylinder of a steam-engine entirely, *i.e.*, sides and ends, or, what is more common, the sides only, with a small annular space—about 2 in. on an average—between the wall of the cylinder and that of the jacket. This space is supplied with a substance capable of transferring heat to the inside of the cylinder, for which purpose steam, or sometimes hot air, is employed. It is with the employment of the former that we are now concerned, the latter only requiring a few words in the sequel.

It is clear that if a transfer of heat is to take place the steam in the jacket must be of a higher temperature than that in the cylinder; steam direct from the boiler, which has not undergone the wire-drawing action of the throttle-valve, is, therefore, employed. It has even been suggested to employ a separate boiler to supply the "jacket" with steam of a higher pressure and temperature than that used in the cylinder. Thus the "jacket" acts upon the principle of a *superheater*, its main object being to preserve the steam within the cylinder in a dry state, *i. e.*, to prevent condensation by supplying the amount of heat the abstraction of which would cause such condensation. It maintains the cylinder at a nearly uniform temperature, and is chiefly applied where steam of high pressure, with great measures of expansion, is used.

To examine the action of the jacket, it is necessary briefly to trace the action and behavior of the steam within the cylinder, which is in contact with the piston and performs the useful work. The steam from the boiler or generator enters the cylinder immediately after the latter has been exposed to the refrigerating influence of the condenser or atmosphere, and is, therefore, of a lower temperature than the steam, in consequence of which heat is transferred from the latter to the material of which the former consists, tending to establish equi-

librium of temperature between the two substances. Now if that steam were sufficiently long in contact with that part of the cylinder, equilibrium of temperature would be established, but as the transfer of heat is not instantaneous, and the velocity of the piston is too great to admit of a complete transfer, that equilibrium is not obtained, and, therefore, the cylinder is never of the same temperature as the steam, nor the steam of that of the cylinder; the resulting temperature will, therefore, be a medium between the two.

This circumstance is only mentioned to show that the loss of heat from this cause is really less than it is usually supposed to be, on the assumption that the cylinder is cooled to the same degree as the condenser, and that from steam entering the cylinder so much heat is abstracted as suffices to equalize the temperature. It also follows from the foregoing, that, the higher the speed of the piston, the smaller will be the loss from this cause.

However, that quantity of heat which is abstracted from the steam will create a corresponding condensation in the latter, lower its pressure, and cause a proportionate waste of energy. But the greater portion of the heat so abstracted is not entirely lost, but simply stored up in the material of the cylinder, because as soon as the communication of the cylinder with the boiler is severed, the steam within the cylinder expands, and its temperature is lowered, because its heat is now distributed over a larger space; therefore heat will now be transferred from the cylinder walls to the steam, and its pressure will be correspondingly raised. It is clear that if the time of contact were of sufficient duration, the whole heat abstracted at first would now be restored, provided none had been lost in the interval from radiation or conduction. The loss of heat thus sustained would only be that due to the property of steam of high pressure not requiring an additional quantity of heat proportional to the variation of a lower pressure; or, in other words, that steam of 100 lbs. pressure does not require twice the amount of heat for its generation, *cæteris paribus*, that is requisite for steam of one-half the pressure, or 50 lbs. This difference, however, is so small in this case, that, practically speaking, there would under these conditions be no loss.

In reality, however, there is loss, because the duration of contact is not sufficient to allow of complete restoration, and a small additional quantity is also lost by conduction and radiation. More heat goes to the condenser as well, since the pressure is higher at the end of the stroke than it would be if no condensation had taken place at the commencement, which occasions re-evaporation at the end. But this can be remedied by shortening the cut-off correspondingly; and consequently only means a reduction in the capacity of the cylinder of the engine, that is to say, the same quantity of fuel would develop the same amount of power, but would require a somewhat—although slightly—larger cylinder.

With regard to the re-evaporation theory, some engineers hold the opinion that there is an extra loss, apart from that due to the property of steam, by which it requires less than double the quantity of heat to generate steam at double the pressure; because, they say, high-pressure steam is condensed, and the heat so abstracted can only re-evaporate the water into steam of a lower pressure. That this idea is fallacious can be proved graphically by means of an indicator diagram. If in such a diagram the terminal pressure is as much higher as the initial pressure is lower, it is clear that the mean will be the same, and that these quantities are equal is certain so long as we deal with the same quantity of heat. Messrs. Bramwell and Easton, for instance, in their report on the machinery exhibited at the Royal Agricultural Society's show at Wolverhampton, point out that high-pressure steam is condensed, but its heat only employed to re-evaporate the water into low-pressure steam at the end of the stroke. Evidently this statement has no reference to the property of steam above-mentioned.

Another source of loss is that the water which is condensed from steam in the cylinder remains in the steam as mist or spray, by reason of which the steam is converted into a better heat-conducting medium; hence more heat is transferred to the cylinder walls, and consequently more is lost.

At the end of the stroke, communication with the condenser is opened, and the steam exhausted from the cylinder and condensed into water of a low temperature. If that communication between cylinder and condenser—or in non-condensers with the atmosphere—is maintained for a sufficient duration, the cylinder will acquire the temperature of the condenser or atmosphere as

the case may be; that this is never the case is corroborated by the fact that during the return-stroke the back-pressure in cylinders of condensing engines is always greater than that due to the temperature of the contents of the condenser, and in non-condensers to that of the atmosphere.

Loss of heat in the cylinder, and corresponding condensation of steam, therefore, is due to the following causes:—1. Radiation from the cylinder; 2. Conduction by the metal; 3. Conversion, in cloudy or wet steam; 4. Refrigeration, by the condenser or atmosphere; 5. Expansion or distribution of heat over a larger space (not in itself a loss); 6, and last, but by no means least, conversion of heat into energy or useful work. (This is not strictly a loss.)

Superficial observers have assumed that the object of the steam-jacket is to prevent loss of heat from the first two causes, viz., *radiation and conduction;* but for this purpose it is not applied, and would, indeed, be worse than useless, because it presents a much larger radiating surface than the cylinder itself, on account of its larger diameter, and, so far as conduction is concerned, it necessitates the employment of more than double the weight of metal than the simple cylinder. Surround the cylinder with a non-conductor of heat, and radiation is cheaply and efficiently dealt with. Of course an air space round the cylinder would be better; a vacuum instead more efficient still; but a good clothing of hairfelt and woodlagging answers the purpose admirably, and is very simple and inexpensive. No engine ought to be without this; it pays for itself in a couple of years.

The prevention of loss of heat from the last four causes enumerated above, is what the advocates of the steam-jacket claim to effect.

The steam within the jacket, which must, as before remarked, by no means be of a lower temperature than that within the cylinder, but if possible higher, supplies the heat to keep the walls of the cylinder at a nearly uniform temperature; therefore the steam within the cylinder will retain all its heat, and no condensation will take place in it, keeping it dry—a bad conductor of heat—and at its initial pressure. During expansion, when the temperature in the cylinder falls, heat converted into work will be replaced from the jacket, tending to superheat the steam, but at any rate keeping it still dry and a poor conductor.

It is easy to see that the pressure in the cylinder must have been higher during the stroke than would have been the case without a jacket, and the power of the engine is consequently increased. But although no heat is lost in the cylinder, the same quantity is expended in the jacket as would have been used in the cylinder, less a very small portion due to convection promoted by wet steam, whereas the tendency to loss from radiation and conduction is increased by the jacket; but, if properly protected by clothing, there will be no material difference from these causes.

So far, then, the jacket has the advantage as regards economy of fuel, since the same quantity of steam has developed more work than would have been the case without it. It should rather be said more steam has done more work, but the increased expenditure is not proportional to the increase of work done.

But there is the return-stroke of the piston to be considered yet, during which the interior of the cylinder is in communication with the condenser or the atmosphere, which will tend again to equalize the temperature, and it is evident that the difference of temperature between the inner surface of the cylinder and the steam in the jacket is now very much greater than during the steam-stroke; hence, the transfer of heat will now take place much more rapidly than before, whereas the heat so taken from the jacket is carried to the condenser or into the atmosphere, tending to increase the work of the former, and the back pressure in each case. It is equally clear that considerably more heat is taken from the jacket during the return-stroke than during the steam-stroke, only a very small fraction of which is usefully employed, so small that, taking all circumstances into consideration, it may be said that all is wasted.

Now, since the gain during the steam-stroke is due to the action of a fraction only of the whole quantity of heat transferred, the loss during the return-stroke must be much greater, because the entire quantity of heat transferred—which in itself is larger than during the steam-stroke—is wasted.

This, then, would seem to settle the point as to economy of fuel; but there are yet other considerations which must not be lost sight of. The steam-jacket has no moving parts, it is true; but nevertheless it is not a favorite with the man who at-

tends the engine, because of the difficulty of making and keeping good joints, especially in jacketed covers; the waste of steam from bad joints is sometimes enormous. It requires more time and more packing materials; and, though this would seem a very trifling matter, it is known that, from this cause alone, the use of the jacket has in some cases been discontinued.

The last point for consideration, but by no means the last in importance, is the cost of the steam-jacket, and on this there is but little to say. The steam-jacketed cylinder engine costs about 20 per cent. more then the unjacketed one. It is unnecessary to comment on this point.

From the preceding arguments the following summary may be drawn:

I. The advantages of the steam-jacket are:

1. It increases slightly the power of the engine.

2. It insures greater immunity from break-downs caused by the accumulation of water in the cylinder.

These advantages are obtained and entail—

II. The following disadvantages:

1. Positive waste of fuel.

2. Increased labor, etc., in its attendance.

3. Increased outlay of capital amounting to about 20 per cent.

From this it is evident that there can be but one reply to the inquiry contained in the title of this paper, Is it truly economical? which must, therefore, be answered in the negative.

Hot-air jackets form exceptions to this case, provided the hot air or other hot gas would otherwise be wasted. But here are the objections: that the extent of superheating is not under such good control as with steam, and if carried too far, impairs the durability of the cylinder by depriving it of a moderate moisture necessary as a lubricant for the piston.

It is to the credit of "The Engineer," which journal most pertinaciously advocates the use of the steam-jacket, that it stated in a leader at the end of 1871 that they had received a letter from a Belgian firm of manufacturing engineers—MM. Nolet et Cie.—who had made elaborate experiments and had arrived at the conclusion the steam jacket was not only not economical, but their engines did better without than with them. The same article stated that an English firm of marine engineers discontinued the use of the jacket because its advantages were so small or doubtful as not to be worth the trouble of making the other joint each time the cylinder-cover had to be removed.

CONTINUOUS BRAKES.

From "The Engineer."

Those who are sceptical as to the desire of railway men to adopt substantial improvements in the means of working their traffic, would, we fancy, have found their doubts set at rest had they been present at the last three meetings of the Society of Engineers. This Society was established, we need hardly state, many years ago; and four or five years since, the increasing number of its members, and their influence and professional position, warranted the Society in taking steps to obtain a charter from the Government. The Institution of Civil Engineers adopted, as we cannot avoid thinking, an exceedingly illiberal and jealous policy. They opposed the granting of the charter, and the Society of Engineers gave way, contenting themselves with the fact that an Act of Parliament of somewhat recent date gave them nearly all the privileges that would ensue from the possession of a charter. The effect, however, of the failure of the Council to obtain a charter operated prejudicially on the prospects of the Society. It discouraged members and arrested progress. Some other matters, on which it is unnecessary to dwell, connected with the financial affairs of the Society—due, in great measure, to the stoppage of all engineering work—did not tend to promote its prosperity. Better times have, however, come for engineers, and during the last year, thanks to the labors of an able president, an active and laborious secretary, and an energetic council, the affairs of the Society have prospered exceedingly, and it now bids fair to assume the position which it is entitled to hold.

Nothing is needed, indeed, but really good practical papers, to confirm its success. The two papers "On Railway Brakes," read by Mr. Fox, are excellent specimens of what such papers should be; and that they have been keenly appreciated is proved to demonstration by the crowded state of the Society's meeting hall in Westminster Chambers on Monday and Monday week. Mr. Fox, as will be seen from our pages, confined his attention exclusively to certain forms of continuous brake, now claiming the attention of railway men; and large numbers of those interested in the working of railways, from Colonel Yolland down to locomotive draughtsmen, have been speakers in, or listeners to, the animated discussion on the points raised by Mr. Fox, which commenced last Monday, and will be resumed next Monday. For many Tuesday nights past the hall of the Institution of Civil Engineers has constituted the arena in which the battle of the gauges is being fought out once more with unsurpassed energy, skill, and bitterness. We have thus both the London engineering societies discussing railway questions night after night, but we venture to think that the discussion carried on by the Society of Engineers is really the more important and interesting of the two. It comes home to us more. It is, no doubt, of great importance that the proper gauge of the future railway of our great Indian possessions should, if possible, be settled; but it is of far more practical importance to hundreds of men concerned in the management of the British railway system, to ascertain whether it is or is not expedient to adopt increased brake power on their lines, and, assuming that it is, then to decide what form the augmented brake power shall take. It is almost absolutely certain that an Act of Parliament will be passed, if not in this session, then in the next, to compel the use of continuous brakes or something equivalent to them on all our great railway lines. The Institution discussion on broad and narrow gauge will hardly be followed by any direct practical result; but it can scarcely happen that the Society's discussion on brakes will, with the possibility of the existence of such an Act confronting us, prove barren and unprofitable. As we have already said, it is impossible to believe that locomotive superintendents or traffic managers are indifferent to questions of improvement. If they were they would not have attended night after night to hear and discuss Mr. Fox's paper; and their action goes far to prove what we have before now urged, that if boards of directors would but leave their locomotive superintendents untrammelled, we should find numerous changes for the better introduced in the working arrangements of our railways.

As the discussion on Mr. Fox's paper remains unfinished, we shall not attempt to do more than deal in very general terms with a few of the points raised. The brakes described by Mr. Fox were, first, Clarke's, as representing the use of chains; secondly, the Westinghouse air brake, as representing the use of the atmosphere; thirdly, Barker's, as representing the use of water; and lastly, Olmsted's brake, as representing the use of electricity. At the first glance it may appear to be a very simple matter indeed to devise apparatus by which blocks may be forced against the rims of every wheel in a train. Those who continue to hold this opinion after they have reflected a little we advise to read carefully the conditions laid down by Mr. Fox as essential to the perfection of a continuous brake. There is not, we believe, in existence at this moment any brake which complies *fully* with *all* the conditions, and locomotive superintendents have to decide for themselves which brake out of several most effectually supplies what they want. Some men will be prepared to dispense with one qualification, others will dispense with another; but the fact remains, that an absolutely perfect continuous brake has yet to be invented, easy as it may apparently be to devise a means of forcing blocks of wood or iron against the wheels of a train.

Although we have no intention of following the speakers regularly through the discussion, we may call attention to some points of interest which were raised. Infinitely the most remarkable was the statement made by one speaker, to the effect that the retardation of a train was more effectively accomplished by wheels just allowed to revolve than by wheels completely skidded. It was given in evidence of the truth of this theory, that Mr. Fay, who was in a sense the father of continuous brakes, tried some experiments years ago with a train weighing 27½ tons. Two experiments were first made with the wheels just gripped sufficiently by the brake blocks to permit them to revolve. A

speed of sixty miles was attained first, and the train ran in each case 240 yards before it came to a stand. Two experiments were then tried with the same train, the only difference being that the wheels were completely skidded, the speed being, as before, sixty miles an hour. The train then ran on both occasions 400 yards before it was stopped. We agree with Colonel Yolland in thinking that the evidence in favor of unskidded wheels requires confirmation. There is, indeed, only one possible method of explaining what, simply stated, is a mechanical paradox. This explanation is, that, in running the first few yards after a wheel is skidded, the point where the tire touches the rail becomes smooth and polished, and the coefficient of adhesion is reduced; whereas, when a wheel revolves slowly every portion is successively brought into contact with the blocks. More work is actually done by the half-skidded wheel, and more heat is generated to use up the work. It is evident that all the work done by a skidded wheel must ultimately be converted into heat; and it is worth considering whether, if such conversion of work into heat were prevented, the work done would not be reduced. Thus, if the surface of contact between rail and wheel were very small, it might chance that the heat could not escape as fast as it was generated, and that there would, in consequence, be a possible loss of work and retarding power. The only way in which the point raised can be settled decisively is to measure exactly the amount of heat generated by a skidded wheel and by one just revolving between a pair of wood blocks. Most heat, most work, and consequently greatest energy of retardation. It is to be hoped that at the next meeting of the Society some one who has tested the point fully will be able to confirm or disprove the accuracy of the results obtained by Mr. Fay.

Colonel Yolland called attention to a very important point in the introduction of continuous brakes. In the South of England generally, and especially on the metropolitan lines, the block system is in use, and the necessity for continuous brakes is very nearly limited to City and suburban lines, where the stoppages are numerous and the stations close together. In the North of England, however, there is a growing tendency to use continuous brakes as a substitute for the block system. We do not think that attention has ever before been called to this point, which is one of very considerable interest to railway companies. It is well known that the cost and inconvenience of the complete block system are so great that in the case of long lines with the stations far apart it is almost impossible to adopt it. If, however, the driver of every train were placed sufficiently in command of his load to be enabled to pull up in a couple of hundred yards or so, the necessity for the block system would, in our opinion, practically disappear, and a new and most powerful reason is supplied for the adoption of a good brake. It is worth notice that Mr. Fox did not describe a single brake that has not been used to a considerable extent in this country or elsewhere, and with a considerable amount of success. Clarke's brake, as is well known, sufficed to render the working of metropolitan traffic possible which, without it, would have been impossible. The Barker brake has been in use two years on a branch of the Great Eastern Railway, and has answered very well indeed. The Olmsted brake, introduced by General Chapin, is in use on a branch of the North London, and although fitted somewhat imperfectly for want of the proper appliances, it has so far, we understand, given good results. The Westinghouse air brake possesses, however, the most important claim on the attention of railway men from the fact that it exceeds any other brake mentioned by Mr. Fox in the extent of its application. It has been tried for such a time, and on such a scale, that it has ceased to be experimental in any sense; and we have no doubt that this point will weigh with railway companies. We are not now expressing any opinion as to the merits or demerits of the brake. We merely state the fact that the invention is, and has been, so extensively used, that there is no room to doubt that any company adopting it will simply follow in the beaten path already well trodden by other companies.

It is more than probable that in the end it will be found that, while all railways will use a continuous brake for their quick traffic, different types of continuous brake will be adopted on different lines. This is as it should be, and such rewards as are going will be shared among several inventors. We would add an earnest word of advice to those who propose to themselves that they will invent a continuous

brake. The work of designing one better than the worst of those described by Mr. Fox would be a difficult task, but it would be as nothing compared to that of getting railway companies to use it. Locomotive superintendents might be willing enough, but directors stand in the way, and who shall propitiate a director? Therefore we say to our readers, don't invent a brake if you can possibly help it. And, above all, do not spend any money on one until you see your way clearly to its adoption if successful. That continuous brakes, however, will ultimately become the rule instead of being the exception, we see no reason to doubt. Their general adoption will constitute an improvement in the working of railway traffic the value of which it is impossible for the railway public at large to realize yet awhile; but these brakes will be the productions of men intimately connected with railway working, and of such men only.

RAILWAYS AND THEIR FUTURE DEVELOPMENT.

By J. W. GROVER, C.E.

From the "Quarterly Journal of Science."

It seems a very hard dispensation, though it is an incontrovertible one, that those who have, perhaps, conferred more benefit upon the country during the present century than any of their contemporaries, should reap so little of the reward themselves. The railway shareholder—I mean the original man who honestly read the prospectus, and believed in its statements, and who backed his belief with his money—was too often a victim to his credulity and enterprising spirit.

Yet, why not? all venturers stand a risk. Certainly, mines are mere sporting investments, to say nothing of the wonderful and fearful enterprises in unknown corners of the American continent, into which the British public plunge with a confidence worthy a better cause. To these, at least, there is a hope of some sort, remote though it be; the story may be true—diamonds may be found in ant hills—and a good round bonus be the occasional reward of the speculator. But the unfortunate railway shareholder has no such hope; if, after years of earnest expectation, he reaches the grand consummation, the *summum bonum* of five per cent., he is thankful, if not satisfied.

Hence, few will embark in fresh railway enterprises legitimately; and this being the case—as it undoubtedly is—we may conclude the summit has been reached. It is true the rivalries of contending companies will induce them to support branch lines, but in themselves these branches are suckers rather than feeders—justly regarded as necessary evils—to be tolerated only where they cannot be avoided, as Dr. Johnson said of notes in books. It is now just four years ago since the Chairman of the London and Brighton Railway Company told his proprietary, who had subscribed four millions towards the construction of a number of branches, that they might as well have used the bank-notes to light their pipes with; therefore several important authorized lines for which the land had been actually purchased, and, indeed, the works partially completed, were abandoned, to the chagrin of the districts they were intended to serve.

Various attempts have since been made, both in Sussex and Kent, to revive these defunct undertakings, hitherto without success, and as the system now stands, the failures are likely to be repeated, and even success itself promises a crop of financial burthen and disaster.

There is a want of something different from what has gone before, and several engineering gentlemen of eminence have given us their ideas on the subject; the gauge question has been revived by Mr. Fairlie; Mr. Fell has brought out the central rail invention, and others equally novel and ingenious; wire tramways, as they are called, have been built for the conveyance of minerals, and suspended railways for the conveyance of passengers on the tops of posts have been proposed by one eminent advocate. Yet still no practical progress has been made, and we find ourselves where we were when we began.

Now, it is necessary to begin at the beginning, and to consider the very elementary principles of a railway's existence, to look at the physical and financial questions fairly, and having them before us, to settle what is to be done in the future: for depend upon it, the less we ignore the teachings of the

past the better; there is no sound progress apart from experience; hence it is that reforms are seldom introduced from without, although it is the external pressure which causes them.

It will be well to deal with the physical questions first of all, before entering upon the financial. The primary conception of a railway is a perfectly smooth, level, and straight road, upon which friction is reduced to the minimum, so that heavy loads may be propelled with the least possible resistance, and at the highest rate of speed.

The earliest type of locomotive engine was designed to run upon such straight and level roads, and it was supposed for many years that locomotives could not climb hills or be made to go round corners.

The first railway carriages were a simple modification of the stage coaches, names and all. It is interesting to look at the curious three-bodied "Marquis of Stafford,"—with yellow pannels and windows, filled with ladies in large coal-scuttle bonnets—as shown in one of Ackerman's early engravings of the Liverpool and Manchester Railway, the only substantial difference being that, inasmuch as the railways of those days were made nearly straight, no arrangement was provided for allowing the axles of the carriage to radiate as they do partially in common road vehicles, but both axles were rigidly fastened so as to be immovable.

Again, as all road vehicles have to turn abrupt corners, their wheels are made to turn independently upon their axles, but so soon as flanges were employed to keep the wheels of the railway carriages between two straight rails, this arrangement was found unnecessary, and to obtain greater strength and security, the wheels were rigidly fastened to the axle, and both were compelled to revolve together.

Now, since the primary conception of the perfectly smooth straight road, a great degeneracy has been of necessity taking place; with greatly increased demands, less capital than ever has been forthcoming; consequently the great cuttings and embankments of early days are being abandoned as precedents, and it becomes necessary that railways should approach more closely to the form of ordinary roads, which follow the surface of the ground only—at small cost.

Hence it follows that the rolling-stock itself must revert more nearly to its original pattern, readopting those contrivances which, under altered circumstances, were discarded.

Still keeping to the most elementary principles, for it is these which are forgotten and misunderstood, and yet they should be engraven on brass and hung up in every railway board room in the world. On a common road, a horse can pull a ton weight in a cart behind him on the level at 4 to 4¼ miles an hour, or, which is the same thing, if a weight of 70 lbs. were hung over a pulley and lowered down a well, he could pull it up at the speed mentioned. It is necessary to be a little explicit, as the remarks in this paper are intended for non-technical readers particularly. Now, if two strips of iron called rails are laid upon the aforesaid road, the friction is reduced seven-fold, that is to say, the same horse at the same speed could draw 7 tons, the difference between macadam and iron being as 70 lbs. to 10 lbs. This immense advantage, however, disappears when gradients have to be encountered, because the resistance due to gravity becomes so greatly in excess of the resistance due to friction, and is constant in both cases. For instance, if on a common road, up a slope of one foot in ten, the horse takes 5 cwt. in a cart over the macadam, if rails be laid down up the same hill, he could only increase the burthen behind him by a little more than 1 cwt., or, in all, 6¼ cwt.; hence, in this case, the value of the rails is nearly lost. Hence the small use of tramways where hills occur.

Upon a very good macadamized road the resistance due to friction is usually taken at about *one-thirtieth* of the whole load carried; that is to say, if the vehicle were put upon a road sloping 1 in 30 it would just begin to move of itself. But upon a railway, under the most favorable conditions, the resistance due to friction has been reduced to the *two-hundred-and-eightieth* part of the whole load carried; that is to say, the vehicle will begin to move of itself on a gradient of 1 in 280. In considering the work which a horse can perform on a tramway, it is important to bear in mind the question of speed; for, according to the experiments of Tredgold, he can draw exactly four times as much at two miles an hour as he can at five, and it appears that at three miles an hour he does the greatest amount of actual useful work, whereas at ten miles an hour only one-fourth of his ac-

tual power is available, and he cannot exert that for an hour and a half; whereas at two and a half miles an hour he can continue working for eight hours. Having these data before us, it is easy to compare the values of steam and horse-flesh:—Suppose coals to cost in the midland districts 18s. 8d. a ton only, or one-tenth of a penny per lb. and assuming that an average locomotive engine will not consume more than 5 lbs. of coal in the hour per horse-power, the cost of fuel per horse-power will be a half-penny per hour. Taking the value of the horse's provender at 1s. 9d. a day only, and supposing he works for six hours, that would cost 3½d. an hour against the half-penny in the case of steam, or, as 7 to 1 in favor of steam; and this result is obtained on the supposition that the horse travels only at three miles an hour.

Now, to sum up the combined advantages, therefore, of an engine on a level railway against a horse on a level common road at 10 miles an hour, we shall find that the former gives an economy over the latter of nearly 300 to 1; at 5 miles an hour it would stand as 115 to 1; and at 2½ miles an hour as 64 to 1.

Such are the enormous advantages of *steam and rails*, and with them does it not seem astonishing that better financial results have not been obtained? There must be something wrong somewhere. As Artemus Ward says, "Why is this thus, and what is the reason of this thusness?"

Speed is the delinquent, and the cause of the loss of the great primary advantages; the vehicles on railways are propelled very fast; hence they involve great strength in their construction, and enormous weight in proportion to the paying load carried.

An old stage coach, according to Nicholas Wood, weighed only 16 to 18 cwt., and would carry upwards of 2 tons of paying passengers with their luggage, or about $\frac{4}{10}$ths of a hundredweight of dead load to every hundredweight of paying load. Now, a third-class carriage with four compartments would represent 2.8 cwt. of dead weight to every 1 cwt. of paying load. Therefore the stage coach has the advantage over the third-class railway carriage of 6½ to 1.

It becomes impossible to institute any absolute comparison between roads and railways at speeds above 10 miles an hour, because such speeds are impossible on the former for any considerable distance. Again, the question of gradient has to be noticed, for in the preceding remarks a level road and a level railway have only been considered.

As has been explained, where steep gradients occur, the resistance due to gravity so much outweighs that due to friction that rails afford a comparatively insignificant advantage, and one which is entirely lost if the stock has to be increased in weight 6½ times.

It may easily be shown that on a gradient of 1 in 10, for instance, taking the foregoing figures, the advantages of a steam-worked railway over a horse-worked road would be a little more than ¼th, if the stock on the former be only 6½ times heavier in proportion than the latter would require. Hence it follows that no railway having gradients of 1 in 10 could be worth making (assuming such to be possible) unless the stock upon it were assimilated to that of the ordinary omnibus or stage coach type.

In former times calculations were made by Nicholas Wood of the comparative costs of conveyance on ordinary roads by horses; he showed that on an average a stage wagon could carry at the rate of 2½ miles an hour profitably at 8d. a ton per mile; that a light van or cart at 4 miles an hour could take for 1s. a mile a ton of goods. Passengers in stage coaches were charged 3d. a mile each, or 3s. 6d. a ton, at 9 miles an hour. Now let us consider what railways actually do. At the present moment coals are conveyed at 5-8d. per ton per mile, at an average speed of 20 miles an hour; and this low rate actually leaves a profit. Excursion trains take passengers at less than ½d. each per mile, at 20 miles an hour, or at 7d. a ton per mile.

Now, bearing in mind the relative proportions of paying and non-paying loads involved in carrying passengers and coals, a simple calculation will show that a ton of passengers could be carried for something less than 1d. a mile, or $\frac{1}{14}$th part of a penny each. For, although passengers require station accomodation, they unloaded themselves, which coals do not.

In the autumn of 1869, the "Times" took up the railway problem, and in a series of very able articles endeavored to show the errors of the present state of things. Although advocated by so powerful a pen, the reforms still remain unaccomplished—indeed, uncommenced. It was then shown

that in practice every passenger on a railway involved over two tons—of iron and timber—to carry him. Or, according to Mr. Haughton (late of the L. & N. W. Railway), no more than 30 per cent. of the load which is hauled by a goods train represents paying weight, the remaining 70 per cent. being dead weight. This seems astonishing, truly, but it is nothing to the passenger trains, where only 5 per cent., or even less, of the load pays, the remaining 95 per cent. being made up of apparently dead and unprofitable material. It is well to keep this clearly in view. In talking about a passenger, with relation to a railway, one must not picture to one's self a respectable English country gentleman, riding, perhaps, some 14 stone, but some Homeric giant, magnified into prehistoric proportions, weightier than an ordinary Ceylonese elephant, and representing about 20 to 25 full sacks of coal, or 2¼ tons.

Yet for three years and more these "facts" have been made manifest, and nothing whatever has been done; and, as matters stand, no alteration of any appreciable extent is possible, or else it would have been effected long ago. High speeds involve high requirements and great strengths in underframes, in buffers, couplings, axles, and the entire fabric of the vehicle, besides in the engine, demanding large fire-boxes and driving-wheels. If trains are to run 60 miles an hour their construction cannot be materially altered without some change in the general system itself. Thus speaks the oracle:—"The railways of the United Kingdom are conducted by an accomplished, scientific, and highly skilled body of experts, who know their business, do it, and don't talk about it; and who, moreover, take out of the locomotive all they can, and present it freely and *exuberantly* to those whom it is their interest as well as their pleasure to accommodate—the travelling community."

These remarks are but too true; the travelling community has been well cared for; perhaps the unfortunate shareholders in future undertakings should be accommodated too—by a slice in what is to be so freely and "exuberantly" given away to those who have taken no risk in the venture.

Let us proceed to dissect the existing state of affairs financially, and see where the money goes, and how. Perhaps the last year or two have been exceptional; we will take three years ago. Out of every £100 earned £49 have to be paid away in working expenses, leaving £51 to be divided amongst those who built the line.

How are those £49 spent? The following table will show generally.

The first three items vary according to the rate of speed employed; they form more than one-half of the whole costs, or 54.54 per cent. A very moderate computation would show that if lower speeds were employed, not only could the stock and engines be reduced in weight, but the wear and tear would be considerably mitigated; the 54.54 per cent would be reduced to somewhat about 36 per cent., or 18 per cent. less, increasing the available balance for dividend from 51 to 69 per cent., or from 5 to nearly 7 per cent.

		Per cent. of Working Expenses.
1.	The maintenance of the way and works costs	18.43
2.	The locomotive powers	27.93
3.	Repairs and renewals of ca riages and wag-gons	8.18
4.	Traffic charges (coaching and merchandise)	28.72
5.	Rates and taxes	4.02
6.	Government duty	2.47
7.	Compensation for personal injury	1.63
8.	" loss and damage for goods	0.95
9.	Legal and Parliamentary	1.44
10.	Miscellaneous expenses	6.23
	Total	100.00

To put the case more simply, suppose a train earns on an average 5s. 2d. per mile, the working expenses would be 2s. 6d. a mile, made up in the following way:—

		d.
1.	Maintenance of way and works	5.53
2.	Locomotive powers	8.38
3.	Repairs and renewals of carriages and wag-gons	2.45
4.	Traffic charges (coaching and merchandise)	8.61
5.	Rates and taxes	1.20
6.	Government duty	0.74
7.	Compensation for personal injury	0.49
8.	" loss and damage of goods	0.29
9.	Legal and Parliamentary	0.43
10.	Miscellaneous expenses	1.88
	Total working expenses	30*d.*

These figures are the A B C of the railway system in England as it now exists, and supposed to be the most perfect in the world, so far as comfort, speed, and constructive skill are concerned; and the most unsatisfactory as far as commercial result goes, returning on the actual outly little over 4 per cent. It ends in this, practically, that on the most perfectly smooth surface a train costs 2s. 6d. a mile to run it, to carry an average of 70 passengers, thus showing an average of nearly 6d. a ton a mile. As

the system now stands nothing better can be hoped for: competition compels extravagance and destructive speeds; and furthermore, the travelling public have been so spoilt by the useless waste of space in the three classes, with smoking and non-smoking division, that any attempt at reform would be vigorously and successfully opposed.

The present enormous weight of dead load to paying load in England is to be greatly accounted for by the variety of classes and the fluctuating demands for accommodation; for to each class there must be a large margin of allowance.

We have—

First Class.
Ditto. Smoking.
Second Class.
Ditto Smoking.
Third Class.
Brake van and engine.

Here we have five different sets of travellers to accommodate; and sometimes, as on market days, there will be three times as many persons of one particular class to accommodate as on others; therefore, practically, on each of the five orders nearly treble the average demand must be provided for. It is all very well for main lines, but on branches something else is requisite. Let there be but two classes—

1. Covered carriages, no smoking.
2. Open side cars, smoking.

And by the use of continuous brakes safety can be increased and a brake van dispensed with.

We should here have two classes instead of five, and, therefore, bearing in mind that three times the average number carried has to be allowed for, a proportion of six to fifteen in our favor. It cannot be too often repeated that what exists cannot well be altered; the public have acquired certain rights by mere custom, and they must be maintained; but it is in view of future undertakings only, that the terms of the new contract can be revised, as between the public and the coming shareholder. It is, after all, the public's best interest to do away with that which impedes railway development, for it is the public who reap the advantage.

When a little branch railway has to be constructed, why should the country expect a scale of magnificence in works and stations like that upon the main line from London to Liverpool; why should the undertaking be saddled with bankruptcy from its inception, and what is beneficial in itself be converted into a bye-word and a hissing. The fact is, that the world, not-excepting engineers themselves, has been educated up to a certain standard of requirements, and hence it is absolutely hopeless to look for any change in England in "Railways." Like the Circumlocution Office, or a Government department, or one of those old-fashioned blowing engines which I have seen in the iron districts, which does its work, and must not be meddled with, or else it would stop altogether, the "machinery" would get out of order by interference, and once out, it could not be readjusted.

A railway is a railway, and you cannot make anything else of it. A "light railway" is a misnomer—a term which has led to a great deal of confusion and loss of money, although it has received the sanction of the Legislature (31 and 32 Victoriæ) —a "light" railway must be a bad railway; therefore it is as well to descend at once from the lofty eminence, and talk about a tramway, *steam worked*, if you will, but still a "tramway" and not a railway; then at once we begin to approach the region of dividend and commercial prosperity, and the investing public can be once more appealed to with prospect of success, and we work on a different scale and without that majesty of design which must end in *disaster* and disappointment.

Before approaching the practical part of this paper, and showing what really ought to be, instead of what ought not, I should briefly draw attention to the fact of a "light railway" in this country being almost an impossibility—not physically, but from the surroundings. I speak from experience: a branch railway is projected on the ordinary system, and receives the sanction of Parliament; a great deal of difficulty is found in raising the money, as nobody will subscribe who can help it; a director or country gentleman, who promises a thousand pounds or two, does so simply out of patriotic devotion to his district—for its development—and looks upon the money as a *fonde perdu*, irretrievably gone. The town to be benefited is canvassed by a few enthusiastic agents, who succeed in placing a few hundred shares of £5 each amongst the tradesmen, who give as they would to a

charitable association. At last it is found that the whole amount got together is infinitely below what is wanted, indeed only a fractional part of it.

Then an appeal is made to the Board of Trade, to give permission for a reduction in the style of construction—light rails, light permanent way, light bridges, light stations, all cheap and bad, and in the end most costly—are sanctioned, and 25 per cent. is knocked off the required capital. All promises well; inspired with fresh confidence, the directors venture on a start, and something begins to show in the country. Then comes the fatal step; the trunk line, which the branch runs out of, never having had any confidence in the little sucker, and having treated it with contempt, if not with hostility, begins to see an actual move, and therefore undertakes to work the line at 50 per cent., perhaps, of the gross receipts. All goes well now, the 50 per cent. agreement is what everybody has been crying out for, and at last have got, but it is a new era of misfortune only—the reign of King Stork over King Log.

The working company, before taking over the new property, instructs its engineer to report upon its condition; he is a gentleman who has been used to the substantial abundance of the past; he does not understand the "light" system; to him a light rail is a bad one. His engines weigh 45 tons with their tenders; and he knows the locomotive superintendent will pick out one of the oldest and worst to work this unfortunate branch, besides a few old coaches unfit for the main line, therefore he cannot accept light bridges. Again, he will find that all the gradients have been made steep, and the curves sharp, to avoid expensive earthworks; this in his opinion, and justly, would actually involve a heavier permanent way than he is using on his main line, and so on, till the whole thing has to be remade; and the working expenses—nominally 50 *per cent.* but, in effect, with all sorts of junction charges and renewal claims, over 65 per cent—entirely swamps the "light system," and its specious and delusive economy.

Wise and able men amongst engineers have seen and felt this, and have freely acknowledged that a branch line must be absolutely something *different* from the parent stem, so that it could not be worked in common with and *into it.* Hence, they have advocated change of *gauge*, apart from its own intrinsic merits, as most completely defining the two systems and preventing their overlapping; it certainly does give to the smaller system an independence and integrity which has great advantages in many ways, but the isolation is too complete in a small country like England, already intersected with lines of a generally standard gauge, except in one or two instances, and these especial. For the undeveloped States of Europe and America, for South America and our Indian Empire, where distances are vast and traffic sparse, a gauge narrower than 4 ft. 8½ in. can be used with some advantage and economy; and if the country is at all rough or mountainous, with a mineral traffic, then the necessity for the small gauge is paramount, for it then becomes a question of small gauge against no line at all.

The little Festiniog Railway, in North Wales, has been frequently illustrated in support of the arguments for an extremely narrow line, for though only 2 ft. wide between the rails it has paid dividends exceeding 12 per cent,—that it has been assumed somewhat hastily that the dividend varies inversely as the gauge, and that by halving the width between the rails the profits can be doubled. The fallacy of this argument is proved at Festiniog itself; for there, even on the face of the same grand mountains, overlooking the same fair valley of the Dwryd river, is another line, not a branch of the first, but rather its continuation to the village of Festiniog, though worked and made by an independent company, which has returned no dividend to its shareholders.

The Festiniog Railway proper has great advantages quite exceptional, and these have been turned to the very best account by the skill and energy of Mr. C. Spooner, C.E., the engineer, who, by adopting the Fairlie Double Bogie Engines, has obtained great power under very adverse circumstances and want of room. Yet it must never be forgotten that the elements of success are manifest. Over one hundred thousand tons of slate annually have to be transported, and all down hill: there is not a fifth of the load to take back in the empties; there is no competition whatever. The toll has been nearly treble, at least over double that charged by any other line for many years; and the line has actual agreements with most of the great quarries by which they would be prevented from any independent action to reduce their freights.

The slates in themselves form a most compact and handy class of goods for carriage. The average speed, moreover, of passenger and goods trains does not exceed 8 to 12 miles an hour. All these circumstances prevent us from taking the Festiniog line as any fair example of a system which would work well elsewhere. To visit it, and to enjoy one of the delightful rides up the mountain side, with the panorama of land and sea around and crags above, and look down on the meadows by Maentwrog spread out as a verdant *parterre*, severed by the silver riband-like stream, is a pleasure to be remembered in a life. There is no such thing to be found elsewhere in the wide world; it is unique, and the enjoyment is accompanied by the exquisite sense of having made some new discovery. Let us for a moment analyze the feeling of having unlearnt the great railway lesson one has been learning all one's life till one visited by chance the vale of Festiniog. For this, and this alone, the journey is worth making, and whoever goes with his eyes open will not return empty; he will feel that his preconceived notions of what was necessary to a railway's existence are torn to shreds and scattered to the four winds. His prejudices of railway education will have been shaken to their foundation, if not uprooted altogether, and he will say with the philosopher of the last century, that "all his knowledge only shows him that he really knows nothing at all."

Hence the great success of this Festiniog Railway as an exemplar. Because it is different it has been taken hastily as perfection, and has been recommended in cases to which it is wholly unsuited. Yet honor to it for its great work. The Russian Empire, the North and Southern Continents of America, and now India itself, have not thought it beneath them to learn from the little Welsh Railway; and it may be truly said that it is the first practical step in the right direction, and has awakened men's minds more than anything else to the necessity for something different, and something better.

It will now be the object of this paper to describe a small and very unpretending "steam tramway," constructed by the Duke of Buckingham for the development of his properties in Buckinghamshire, which in the writer's opinion seems to offer the most universally applicable example of what branch railways must be in the future in England, and perhaps in less developed regions of the world's surface.

This little line was commenced on 8th September, 1870, and the first four miles from Quainton as far as Wotton, were opened on the 4th April, 1877; the greater portion of the remainder was used for mineral and agricultural produce in November, 1871, but the last quarter of a mile up to Brill was not brought into use till April, 1872. The main line is nearly seven miles long, and the gauge the same as that upon the adjoining railways, viz., 4 ft. 8½ in.

The cost of this "steam tramway," including sidings and two goods sheds, was rather less than £1,400 a mile without land, which belongs principally to the Duke of Buckingham. The gradients between Quainton and Wotton are favorable, the worst being 1 in 78. But from Wotton to Brill they are comparatively heavy, varying from 1 in 100 to 1 in 51, the total ascent in the last three miles being 130 ft. The line is worked by Messrs. Chaplin and Horne, but the maintenance is undertaken by His Grace the Duke, who executed the work with the assistance of his own engineers, and without a contractor. The expenses of maintenance (and certain other works) is at the rate of £380 a year; the total working expenses being estimated at £650, including 10 per cent. interest on two engines; the earnings being at the rate of about £1,350 to £1,400 a year, leaving a profit for dividend at the rate of over 7 per cent. on the outlay, exclusive of land in the first year, a result probably without parallel in the history of English railways.

This little line traverses the most ordinary agricultural country; there are no great slate quarries or manufacturing establishments to create any exceptional trade. The case is one which affords a striking instance of what can be done by steam and rails in common English country. The traffic consists of coal, road metal, manure from London, and general goods inwards; of hay and straw, grain, timber, bark outwards; of cattle inwards from Herefordshire in spring, and fat cattle to London in the winter.

The coaching traffic consists of passengers and milk, at present carried by a Great Western composite carriage, which has been borrowed, and which weighs 8 tons, a great deal too much for the work it has to do.

The line is worked by one 6-horse Aveling and Porter engine, weighing less than 10 tons, and costing about £400. The engine makes two double trips a day, and a second one is now provided. The former is found sufficient, and very low rates are charged, London manures being brought at 1d. per ton per mile throughout.

It should be observed that these engines have no springs, and consequently travel somewhat roughly. Perhaps too great economy has been sought in them; an expenditure of £600 would have insured a really efficient machine.

The speed employed varies from four to eight miles an hour, and it was not intended to carry passengers at all in the first instance; but the demand for accommodation in the trains was so great that the passenger carriage had to be borrowed, and the numbers carried were 627 in the first four months of last year.

Unfortunately, no statements of the actual costs and earnings are published beyond April last; but the impulse to trade and agriculture, due to the tramway, is extraordinary; and has exceeded the best expectations. The district served is one by no means densely populated, on the contrary, the whole of the villages, including Brill, do not total up to more than 2,000 persons, or less than 300 a mile. Three years ago, the idea of making a branch railway to serve such a district would have been considered insanity; for all over the country branch lines are seen, having actual towns upon them, which nevertheless cannot pay any dividend at all, and are frequently obliged to appeal for refuge to the "Court." Yet here we have an actual proof of the capabilities of iron and steam to serve a district, and not to forget its shareholders; for, even after allowing something for the cost of land and administration, such as might be contingent on an enterprise carried out without the aid of one great proprietor, there is in the Wotton revenue a good balance on the right side.

It is only right, in concluding these remarks on this curious branch, to say that there are no platforms, the rails weigh only 30 lbs. to the yard, and the line is not fenced except in grazing meadows; at each main road crossing there is a siding for trucks; the guard issues tickets whilst travelling in the train, the tickets being torn from a book as in a tramway-carriage; one ordinary train is instanced as a fair average down; it consisted of the engine, a Great Western railway-carriage, five empty coal trucks, and three trucks laden with hay, which altogether weighed about 50 tons.

The staff of servants working the train consists of one engine-driver, one brakesman, and one guard; at Messrs. Chaplin and Horne's offices, at Brill, there is a manager and two clerks. The principal traffic is in coal, of which from 100 tons to 140 tons go up weekly.

How many parts of England, and more in Scotland and Ireland, are languishing for want of such humble but efficient steam tramways; how enormously might the productive powers of the soil be increased by such easy access to and from the railway system; every farmer might have the railway wagons brought to his homestead, giving him cheap lime, coal, and manure, and taking out his hay, straw, and cattle; and furthermore, what a field is here opened out for the investment of capital now seeking employment and only finding it in foreign enterprises. By a little careful selection of the country, by the co-operation of the land-owners, and with the aid of an occasional paper mill, quarry, or manufactory, such undertakings might be made to pay large and handsome dividends, very much exceeding those obtained in the Wotton tramway. Their development and their success must depend on the land-owners themselves; if they will obstinately persist in making all kinds of monstrous claims for severance and land, no investor could reasonably be asked to embark in the scheme; but if they would content themselves with fair rent charges and agricultural values, their properties might be benefited in a way to yield them handsome returns.

As such tramways must necessarily follow the surface of the ground to a great extent, avoiding heavy earthworks, it is worth while to consider what really are the limits of gradient.

If we take two pieces of clean iron and lay one on the other, and gradually lift one end of the lower one till the superincumbent piece begins to slide, we shall find that this sliding takes place at a slope somewhere between 1 in 4 and 1 in 6; this, therefore, is the ultimate co-efficient of friction, and varies according to the condition of the surfaces in contact of the metal.

Let the uppermost piece of iron be taken

to represent the engine, the lower one the rail; the wheels of this engine being locked and prevented from turning, it will just stand at 1 in 4 to 1 in 6; therefore, if the wheels are caused to revolve, it can just climb this gradient under the most favorable circumstances.

But rain, fogs, and sleet prevent this result from being arrived at in practice, and engineers seem to agree that 1 in 10 is the most that can be climbed in all weathers with certainty; therefore, taking this as the *datum*, up half that gradient, or 1 in 20, the engine can take a load behind it equal to its own weight, and up 1 in 30 twice that weight.

Therefore a 10-ton engine can haul 20 tons up 1 in 30, or two loaded wagons, of say 5 tons each, carrying 10 tons of paying load; the non-paying load being 10 tons.

It would appear, therefore, that 1 in 30 is about the steepest incline which should be adopted for any length; this gives a rise of 176 ft. in a mile, and practically commands most countries.

Near Aberdare Junction, on the Taff Vale Railway, ordinary locomotives can be seen regularly working up 1 in 18, which is a practical proof of the foregoing statements; they take loads behind them of 45 tons.

Between Manchester and Oldham, where the traffic is enormous, the gradients reach as high as 1 in 27—and ordinary locomotives with coupled wheels climb this, with loads behind them of 60 to 80 tons regularly.

These instances merely show extreme cases, neither to be copied nor commended, but, where occasion requires, to be employed sparingly as precedents.

If 1 in 30 be the worst place on the tramroad, a 10-ton engine could nevertheless haul two cars containing over 150 passengers up it; this would be more than would be requisite in an agricultural district.

Having roughly defined the limit of gradient, let us finally consider the curves possible, for, after all, these are the most important questions of all; we have seen that we can get over hills, but we now require to go round corners, or very sharp elbows, as explained before in this paper; the axles of railway carriages are firmly fastened underneath, so that the vehicle has no tendency to follow the curve or lock as an ordinary four-wheel vehicle upon a common road has; hence engineers seldom adopt curves sharper than 660 ft. radius on railways, although there are instances as low as 300 ft.: the travelling becomes very bad, and the grinding is fearful. That something better can be done has been demonstrated during the last two years; any one can see, in daily use, at the Fenchurch-street station two railway-carriages of four wheels each, mounted on bogies in such a way as to be able to go round very sharp corners; these vehicles are mounted on Grover's patent under-frames, and the results obtained by them in the duration of their tyres, and consequent absence from friction and grind, have been remarkable.

It is true that the ordinary 8-wheeled double bogie vehicle in use on the American railways will do the same thing, but the enormous length and weight of such cars prevent them from being employed profitably on steam tramways; what is really wanted is a short handy vehicle, capable of being shunted and moved about at the station by a couple of men easily.

With respect to the question of engine there is not so much difficulty; a small traction-engine has its wheels very close together, consequently it will take a sharp curve without difficulty; besides which, Mr. Fairlie has constructed engines on his double bogie system, which have immense power, and are capable of going round curves of 50 ft. radius; in mountain districts these engines are most valuable, and enable gradients to be worked easily which would otherwise be almost impracticable.

In South America they are in daily use, taking loads of 120 tons up a gradient of 1 in 25, continuous for 11 miles on the Iquique Line, and also on the Mexican railway.

It appears, therefore, that the necessary mechanical difficulties have been practically surmounted; all is ready to hand, the engineer has it in his power to overcome the obstructions which nature has laid in his way, and those only remain which are due to the prejudice of education and human nature; a great lesson has been learnt,—which must be unlearnt,—but the task is not a difficult one if it be met with the spirit of sincere attention and honest endeavor.

A few words more before concluding, on the management of existing railways as they stand. It has been taken far granted that, where high speeds are adopted,

no substantial change can take place in the strength of the vehicles or the weights of the engines; but why should not express stock be kept distinct, and a considerable reduction be made in that which is meant for ordinary service? Such an economy is being effected on the South London Railway by the present locomotive superintendent, Mr. Stroudley, who has constructed some light and neat carriages, with central buffers, drawn by small engines weighing only 23 tons; these trains are worthy of imitation—they are a step in the right direction, and if more fully adopted would give better dividends and reduced fares. The real fact is, that great obstacles are placed in the way of railway officials, in consequence of the division of their responsiblility. The locomotive superintendent thinks little about the permanent way—which is not under him, but adopts great strengths and weights, whereby he increases the "life" of his stock. The engineer who has charge of the permanent way complains, but has no remedy. No real improvement is possible until some ruling mind governs each system, and insists upon comprehensive reforms and the adoption of those inventions which guarantee sure economies.

EFFECTS OF RAILROADS ON THE VALUE OF LANDS.

By Gen. W. S. ROSECRANS.

Written for Van Nostrand's Magazine.

Railways already cover our country with a net work of iron rivers along whose channels commerce swiftly travels, distributing necessaries, multiplying comforts, diffusing luxuries and unifying social habits and political ideas.

Every year adds to their number, and extends lines and branches.

Their growth is without precedent, and outstrips all experience. Their owners, managers, and the general public are continually behind in comprehending their workings and effects, and obliged to accelerate studies and multiply efforts to overtake the growth of the system and determine the laws of its operations and effects.

How far behind they are may be inferred in part, from the published annual reports of our railway companies, very few of which give such results of experience in the operations of their roads as are necessary to determine the laws of their working, and economies.

It also appears that the owners of the 2,000 millions of dollars capital invested in them lack the knowledge needful to that ownership, while an enthusiastic public feeling its impulse, yet but feebly comprehends the magnitude of the effects of these roads on the values of industry and property.

The fact that with us this influence has been combined with others has made it more difficult of measurement. Immigration and proprietary labor have added immensely to the value of lands in the United States. Without here inquiring how much the activity of these forces has been stimulated by railroads, experience and reason teach that they must have had a great deal to do with the enormous increase in the value of lands, attested by the grand levy rolls of taxable property in all our States.

It seems obvious that, like all others, these effects must be governed by fixed laws.

Having been led to give this subject some study, it has appeared to me that railway owners and managers, legislators and the public might all be interested in some of the conclusions reached.

Their publication may also serve to direct attention to the importance to owners and managers of railroad property, and to the public, of having made and published such official reports of the operations of each line of road as would give all the elements needful to determine their essential laws with as much certainty and exactness as have been attained in life insurance and underwriting.

It may also direct public thought to the fact that next to the influence on the value of property exercised by the currency of the country, is that of our railroad system.

Whence follows the necessity for the utmost care and attention to provide and legislate for their just and economical management, in which the people, especially the toilers, have as great if not as direct interest as the owners of the roads

PRELIMINARY ABOUT LANDS.

Lands whose products cannot be taken to market are worthless, except, perhaps, for occupation or some future prospect. Their owners may be able to draw therefrom the necessaries of life. This amounts to insurance of constant employment at wages that secure the necessaries, and that the owner shall be his own employer. Whatever these may be worth, such land would be worth.

But this value is nominal.

When transport of products is possible, those most cheaply transported, as live stock, which may be driven, or such as have the largest market value per pound—precious metals, cochineal, indigo, tea, coffee, etc., are the first to give the lands value. After them come other ores—metals, fruits, grains, timber, etc., the ruling elements in the value all the while being the expense of transporting the products to market.

THE GENERAL LAW.

Assuming that land has no cash value beyond that distance from a market for its products, whence the cost of transporting added to that of producing them exceeds their net value in the market, the general value of an acre inside this limit may be stated thus:

$$(1)\ A = \frac{Q}{R}\cdot (v - c - hx).$$

in which

A = the cash value of the acre.
Q = the number of centals (100 lbs.) the acre will annually produce of the crop.
R = the per cent. interest yearly of money.
v = the net market value of a cental of the crop.
c = the cost of producing the same ready for market.
h = the price of hauling it one mile, and
x = the distance to market in miles.

This applies to any kind of product, hauling and distance, and substituting therein the proper numbers for the particular case the resulting value of A will be the price per acre sought.

From this we obtain:

RULE I.

To calculate the cash value of an acre of land for any kind of crop:

From the average net market price of a cental of the crop subtract the cost of producing it ready to be sent to market, and the price of hauling to market; multiply the remainder by the number of centals of the crop the acre will annually produce; divide this product by the rate of interest per annum; the quotient will be the price per acre sought.

RULE II.

To find the greatest distance from market at which any product will pay:

From the net market value of a cental of product subtract the net cost of producing it ready for sending; divide the remainder by the cost of hauling one *cental one mile*; the quotient will be the distance sought.

RULE III.

To find the difference in the value of an acre due to a mile of distance of hauling for the crop:

Multiply the number of *centals* annual average produce of the crop per acre by the cost of hauling *one cental one mile*, divide this product by the rate of interest; the quotient will be the difference sought.

These rules are applicable to all kinds of lands, productions, hauling and distances.

The values of the elements they involve seem numberless, but are not greater than those affecting the duration of human life or risks on property. Life insurance and underwriting have been reduced to scientific exactness; and doubtless like exactness exists and may be attained in calculations from these rules by proper care and attention to facts.

But even without great accumulations of facts to guide, general averages judiciously assumed and used will show pretty clearly the measure and law of influence of the cost of transportation on all the products of a nation's industry.

As a special case let us assume averages to show

How it affects the value of tillable lands.

Good husbandry and necessity both tend to vary the kind of crops; while the soil, the seasons and the husbandry, all vary the weight annually produced by an acre of tillable land.

The assumption of general averages will be necessary, but like insurance averages they may be made substantially exact.

Low averages will be taken, that the results obtained may fall below rather than exceed those of practice.

Assuming the annual average product of an acre at 12 centals (1,200 lbs.) of crop,

worth a net average of 135 cents per cental, and costing 75 cents per cental to produce ready for market, interest being 6 per cent., our general equation (1) becomes $A=120-2hx$.

Whence we have

RULE IV.

To obtain the cash value of an acre of tillage land bearing the average:

From $120 subtract 200 times the price of hauling *one cental* one mile multiplied by the number of miles to market; the remainder is the price per acre sought.

RULE V.

To find at what distance from market the acre ceases to have value:

Divide 120 by 200 times the cost of hauling one cental one mile, the quotient will be the distance required.

RULE VI.

To find the difference in the value of an acre due to a difference of one mile in its distance to market:

Take 200 times the cost of hauling *one cental* one mile.

From the foregoing we find the acre at the market worth $120; and for every mile away its value is less by 200 times the cost of hauling *one cental* one mile.

Hence the greater the cost of hauling, the more rapid the decrease in values.

Hence also the paramount importance to the farmer of having the shortest and best road to market, since every extra mile, or bad place in the road equal to a mile, takes away so much from the value of each acre; how much we shall now see.

Considering the condition of country roads at different seasons, and allowing for hauling what will pay interest on the cost, and make good the wear and tear of animals, gears, and vehicles, keep the teams and give the teamsters fair wages, 30 cents per ton per mile is probably a low average price.

Three cents per ton per mile is at present a fair average for agricultural produce per railroad.

At these rates a cental transported one mile would cost 1.5 cents by wagon and 0.15 cents by rail.

This makes the value of the acre decrease for every mile away $3 by wagon and 30 cents by rail.

These are figures for farmers to ponder. How easily a mud-hole could take $3 an acre off the value of his land! How easily an extra mile of road would do it.

We also see that at 40 miles away by wagon road, the value of the acre becomes nominal; while by railroad it does not become so until 400 *miles away*.

The railroad then moves land from four hundred up to forty miles by common road from the market.

This is when it freights at 3 cents per ton per mile, or 0.15 cents per cental per mile. Were its rate *two cents* the point of nominal value would be 600, and at *one cent* 1,200 miles away.

What immense values depend on having railroad transportation, and having it as cheap as possible!

The introduction of railway hauling, wherever possible, is evidently a paramount local and high public interest, and at once raises the question:

How cheaply can railroads be built and operated to do freighting at our assumed average; and how much lower can the rates be brought and made to pay well?

We have seen what marvellous effects on the value of the acre resulted from supposing the rates reduced to *two cents* and to *one cent* per ton per mile by rail.

A change of any per cent. in the rate of freight, will increase the length of the limit line at the same rate, and the aggregate value of the land within the limits by the *cube of this length*.

Could anything be more significant to show the interest of the whole body of the people in the economical construction and management of roads?

From our formula (2) $A=120-200\,hx$.

We see that the acre, at the market worth $120, at any other point is worth $200 less 30 cts. multiplied by its distance away. It is also clear that at any such point an acre off the line would be worth *three* dollars less for every mile its prpduce must be wagoned to the road; and when that distance multiplied by *three dollars* equals the value on the road, its price would be nominal. Hence the values on every mile wide strip across the road makes a double decreasing arithmetical series, the middle term being the price on the line, the extremes be 0 and the common difference $3.

With our assumed data the railroad affects the value of land within an *isosceles* triangle having an altitude of 400 miles on the road

and a base of 80 miles at the market. Within this arc the values per acre vary according to laws above explained.

As our purpose is to ascertain *general laws* and illustrate their importance, we shall assume that, within the road's influence, the production from the land may be such as to make it equivalent to being all tillable and capable of producing the annual averages already used. Nor will this appear extravagant, when it is considered that mines, ores, quarries, fuel, timber, lime, water-power, and whatever has a market value, are productions of the land in the business sense of the word. It will also be assumed that every mile of the road is a shipping point for these productions, and that every mile-wide belt across has a wagon road to bring its products to the road.

If we compute the aggregate value of the land within this area, and deduct therefrom the value of that part of it next the market, which had value, as we have seen, by wagon haulage, the remainder will be the enhancement due to the road. Dividing this by the whole area, gives the enhancement per acre, and by the length of the road, the average per mile of road.

Before making the calculations, let us take *a strip one mile wide and 400 miles long*, having the railroad along its midline. This contains 400 square miles, or 256,000 acres averaging $60 per acre, or a total value of $15,380,000.

Without the railroad 40 miles of this strip next the market, 256,000 acres, was worth $60 per acre, making a total of $1,538,000, which, taken from the above aggregate, leaves $13,824,000 net increase in the value of the land due to the operation of the railroad. This is an average of $54 an acre, or $34,560 per mile of road.

Did this strip extend only 200 miles from the market, the average increase would be $90 per acre.

But the road *adds value to all the improvements on the land*, makes business much easier to transact, and hence the owners of the land could even *afford to pay* $34,000 *per mile* to secure the operation of the road along their property, and would then be gainers.

And as $13,284,000 is added to the value of the lands, the State gets that addition to its taxable property, and is thereby gainer by whatever this sum will yield of net taxation. Were the State's net income from land-tax *one* dollar per hundred, this sum would produce $138,240, to produce which would require a capital of $2,304,000 (two millions three hundred and four thousand dollars) at 6 per cent. per annum. This equals $5,760 per mile of the road directly gained by the State.

As we shall see from subsequent tables, had this strip been *six miles* wide the State's gain direct would have been $25,446 per mile of road.

We will now proceed to complete the whole area and aggregate value of the land within the road's influence.

Without encumbering the article with details, for the convenience of those who desire to make similar calculations I stated that equations used were

$$V = 640\,\frac{Q}{r}\cdot\frac{(V-c)^3}{3\,h\,h'} \qquad (4.)$$

$$V = \frac{h}{h'}\,\frac{d\,r^3}{c} \qquad (5.)$$

in which V = the entire aggregate of values; Q = the centals of produce per acre; r = the rate of interest; V = the net market value of a cental of produce; c = the cost of producing it; h = the cost of hauling one mile by rail—h' the same by wagon; d = the difference in value per acre for *one* mile by rail; and r = the distance from the vertex of the triangle to any point on the line towards the market.

The area of the whole triangle is 10,240,000 acres; and its aggregate value $409,600,000, averaging $40 per acre.

If from this aggregate we take the value of that part next the market, a semicircle of 40 miles radius which had value by wagon haulage amounting to $16,007,280, it will leave $393,592,320 net enhancement of land values due to the road. Hence a single line of 400 miles of railroad proceeding from a general market at the averages assumed, adds $393,592,320 to the value of the lands alone; which is an average of $983,980 per mile of road. Were we to consider the first 200 miles only, the gross gain to property would be $342,392,720; the average per acre $45.36; and the average per mile of road $1,711,968. And for a road 100 miles long from the market, the gross gain to the lands would be $220,992,729 or $2,209,927 per mile of road.

Should any reader be filled with surprise and amazement at these enormous sums, let him observe the careful steps and mode-

rate averages used in obtaining them, and he will see that they are the expression of an *incontrovertible law*. Nor will its verity be materially affected by local variations from our averages. No one, perhaps, dies exactly at the time computed for him by the *tables* of mortality, yet the average person of his class *never* outlives the time computed by the Tables.

The immense gains to landowners thus shown, will be participated in by the State, which gains to its taxable property the same sum, $393,592,320.

This, yielding from taxation a net of $1 per hundred, would produce $3,935,923, equal to a capital of $65,598,717 bearing 6 per cent. per annum in perpetuo; or $163,-996 per mile of road. And as we have just seen that the ratio of gain per mile to local owners, increases very rapidly with the diminution in the length of the road, so would the States' proportional interest increase thereby. The general rule evidently is that the State always gains by every rise in the value of taxable property; and that its interest is to that of the owners, as the net tax per $100 is to the net annual interest per $100.

These are direct gains, but the indirect ones are manifold and important. *Besides* the saving of time in doing business, the cheapening of administration, the distribution of labor, the development of resources, are all the higher elements of civilization and progress, the attainment of which alone would probably warrant the construction of the road at the expense of the State.

It may be said that our roads are mostly too near each other to admit of the assumption of so large an area as we have considered, belonging to one road.

True; but we have already seen that the shorter the line the greater the relative gain, and it may readily be inferred that the nearer the lines to each other the higher the value of the land.

One has only to reflect on what has been explained to see how this is.

Lines of railroad, already much nearer than contemplated in our example, are continually multiplying.

The interests which impel this multiplication appear in the foregoing.

How nearly they may approach and find business to support them depends on many things. That there must be a limit somewhere is evident, but with us hitherto, no sooner has prudent conservative reasoning fixed one, than enterprising experience comes in, builds and operates a paying road and removes the limit.

As the extension of railroads and the multiplication of lines and branches possess special interest in the light of our discussion, we shall append a table taken from Poor's "Railroad Manual" for 1868-9, giving the comparative number of square miles and population to one mile of road, on the 1st of January, 1868, since which time our lines have increased 35 per cent. in total length.

Comparative Table of the Ratios of Population and Square Miles Area to one mile of Railroad.

—	Miles of R. R.	Area to one mile.	Populat'n to one mile.
Maine	521.0	67 0	1270 0
New Hampshire	667.0	14 0	500.9
Vermont	587.0	18.7	1061.
Massachusetts	1401.0	5.5	927.0
Rhode Island	125.	10.5	1520.1
Connecticut	637.	6.4	8161.
New England	3938.	16.4	843.
New York	3245.	14.4	1325.7
New Jersey	942.	8.8	922.5
Pennsylvania	4311.	10 7	765.5
Delaware	162.	13.1	740.7
Maryland & Dist. Col.	527.	21.2	1442.1
West Virginia	365.	64.9	1041.1
Middle States	9552.	14.5	1016.6
Ohio	3398.	11.7	7490.
Michigan	1463.	38 6	649.3
Indiana	2306.	14.6	693.6
Illinois	3224.	17.2	713.5
Wisconsin	1036.	52.0	989.4
Minnesota	482.	173.3	747.
Iowa	1283.	42 8	760 2
Nebraska	555.	137.0	2250.
Kansas	494.	164 6	457.5
Missouri	985.	66.4	1370 5
Western States	15226.	39.4	753.9
Virginia	1452.	21.3	900.0
North Carolina	1042.	48.6	1000.7
South Carolina	1007.	29 1	700 0
Georgia	1548.	37.4	710.6
Florida	437.	135.7	343 2
Alabama	851.	59.6	1152.0
Mississippi	898.	52.5	890 0
Louisiana	335.	123.4	1970.0
Texas	496.	480.0	1512 1
Kentucky	635.	59 2	2000.0
Tennessee	1358.	33 6	773.2
Arkansas	38.	1373.4	13157.8
Southern States	10097.	60.6	1026.0

	Miles of R. R.	Area to one mile.	Population to one mile
California.....	382.	494.7	1309.0
Nevada.....	30.	3736.6	2333.3
Oregon.....	19.	5000.0	4200.5
Pacific States.....	431.	919 6	15081.
Aggregate of the U.S.	39244.	49.4	905.1

From this table we see that at the date named the average width of the belt of land sustaining a line of rail land, good, bad, and indifferent, tilled and untilled, was in :

New England,	16 4 miles;	average,	1325 7	people.
Middle States,	14.5 "	"	1016 6	"
Western States,	39.4 "	"	753 9	"
Southern States,	60.6 "	"	1026.0	"
Pacific States,	919.6 "	"	1508.1	"
And in the whole country,	49.4 "	"	905.	"

Since the date of this table there has been an increase of nearly 35 per cent. in the total miles of railroad line in the whole country, bringing the average breadth to about 35 miles. In Massachusetts 5, and in Connecticut 6 miles in breadth, sustain a mile of road.

In consequence of these varying widths of belt per mile of road, the following table has been computed for our hypothetical case, using the formula already explained, and the same averages. Let it be observed that in the computations no additions were made to express the increased values due to all incidental effects of the road.

Table showing the Areas and Aggregate Values, and the Average Values per Acre of various widths of Land four hundred miles long, having an operating Railroad along the mid-line, freighting at 3 cts. per ton per mile.

Width of Belt. Miles.	No. of Acres therein.	Total Value.	Average per Acre.
Whole.. .	10,240,000	$409,600,000	40.00
2 wide ...	505,600	29,958,400	59.25
4 "	998,400	58,419,200	58.51
6 "	1,478,400	85,420,400	57.78
8 "	1,945,600	111,001,600	57.05
10 "	2,400,000	135,200,000	56.33
12 "	2,841,600	158,054,400	55.62
14 " ...	3,270,400	179,603,400	54.91
16 " ...	3,686,400	200,624,400	54 15
18 " ...	4,169,600	219,137,600	53 58
20 "	4,480,000	237,600,000	53.01
22 "	4,857,600	253,510,400	52.19
24 "	5,224,000	269,107,200	51.51
26 "	5,574,400	283,628,800	50.88
28 "	5,913,600	297,113,600	50.24
30 "	6,240,600	309,600,000	49.61
32 "	6.553,600	320,826,400	48.95
34 "	6,854,400	331,731,200	41.39
36 "	7,142,400	341,452,800	47.81
38 "	7,417,600	350,329,600	47.22
40 "	7,680,000	358,400,000	46.66

The table shows that on a strip four miles wide and 400 long, the road being on its mid line, the average value of the acre is $58.51. For eight miles it would be $57.01. For sixteen miles wide, about the average breadth for New England, it would be $54.15. Lands of higher grade are benefited in a greater ratio; lands near the market, as has already appeared, bear much larger averages, and the shorter the line of the road the greater the average per acre or per mile of road.

Without repeating what has been said of the indirect effects of the road on the many values of other property, we may say in general that in all these as in the direct gains the general public and the local owners are joint participants, their relative interests being as the States' net tax income per cent. is to the interest income to the owners of the property.

I think from what has been said, the irresistible inference will be that next to the proper management of the currency, the standard of all values, we have the highest interest in the cost and management of our railroads, which, even now, like currency, have the power to raise and lower the value of nearly all the farming and manufacturing property of the country.

I have not laid special stress on manufacturing products; but they follow the general law; and it is evident that a railroad line can almost create and destroy, at will, the value of manufacturing property by varying its rates of freighting. Nor does the exercise of such powers concern alone the owners of the property and the public; but all the farmers and furnishers of raw material are interested in retaining manufactures as near to them as possible, because it gives a home market for products that would not bear distant transportation.

And since the public interest is so great and direct in their cost and management, it is clear that every report and record of experience that can assist in bringing these to perfection should be secured and availed of.

None better than the great railroad property owners and managers know how imperfect, as yet, are the systems of accountability and management of most of our railroads, and how much even the best informed have to learn.

A careful analysis of the published annual Reports of Roads, show how extremely

imperfect and inadequate they are in giving such accounts of their operations as are necessary to a thorough business comprehension of what they are doing, and how well or ill they are managed.

A few great companies, renowned for good management, show that they comprehend this, and give the information needful alike to their own management, to their owners, and the public.

This article of information and suggestion has been written for the general public rather than for those whose business is the construction and management of railroads. I shall therefore take the liberty to summarize a few maxims and conclusions for those for whom I write, which will doubtless appear trite enough to railroad men, but which I think will be convenient and useful to the public, and possibly not do any harm to some of those engaged in the business.

To mankind, railroads are potent instruments.

For emancipation from the effects of climate and locality.

For diffusion of knowledge and of the arts.

For distributing necessaries, comforts, and luxuries, and for increasing culture and civilization.

To the statesman and political economist, they are *iron rivers*, *navigable ways* of *transport* and *travel*, having the essential effects of ocean borders, lakes, and rivers on *National Unity*, *National Defence*, *National Commerce*, and *Industry*, capable of being made to run wherever the wants of actual or prospective population, or the national interests may require; assimilating the habits and tastes of the people, and unifying political interests and ideas.

But, to the great body of the people, owners of property, and producers from labor—to that great pyramid of interests resting on the basis of our agriculture—they are the veins and muscles, the circulation and force of business life, and to railroad owners and managers *a new and cheap way of hauling men and things*. To these vast pecuniary interests the cheap cost and thoroughly correct management of railroads is of controlling importance. They want all the laws which govern their proper construction and management; and the mode of measuring their effects on property and industry, thoroughly ascertained and determined. Nor, though they may feel less the need of it, are the owners and managers of roads less concerned. They hold in their hands a system so directly controlling the interests of property that a thorough comprehension of its use is necessary to enable them to meet the responsibilities to which, sooner or later, they will, as surely they ought to, be held by an intelligent people.

In view of the interests of the present and future of our railroad system, let it be borne in mind that the following ought to be maxims:—

1. Every proper extension of an operating railroad is a direct gain, locally to property and industry, and generally to the State, in the ratio of the rates of interest and taxation.

2. Every unnecessary dollar it is made to cost is a direct damage, locally to property and industry, and generally to the State in the same ratio.

3. Every error or wrong in management which increases the prices of freights is also a direct damage to local property and industry, and to the State in the ratio of the rates of interest to taxation.

4. Hence, every line of road should be constructed in the cheapest way consistent with the adequate performance of its work and true economy in regard to durability and safety.

5. It should go by the shortest practicable route from where the men and things to be hauled are, to where they are to go; because every extra mile of travel is a direct local loss and general damage.

6. Extra mileage is not only a loss of time but costs the Road a sum of money annually, which is equal the interest on the amount it could afford to expend to avoid the extra mile. If the average annual operating expenses were $700, it could afford to expend $100,000 at 7 per cent. interest per annum in perpetuo to avoid an *extra mile* of distance.

7. Hauling unnecessary dead weight is a dead weight on the interests of the people as well as those of the owners.

8. Unnecessary train mileage for "service" and switching, etc., switches the interests of the people along the line, and the interests of the State as well as money out the pockets of the road owners.

9. Every unnecessary shake of the ground caused by the "thundering of the trains," shakes money out of everybody's pockets having interests in railroads—and who has not?

The import of some of these observations will appear more significant when it is stated that an average of 131 of our best managed roads, whose reports are full enough to admit of calculating these averages, shows that

Of the weight going over the roads in freight trains only 0.286 or 286 lbs. out of 1,000 pays freight; and

Of the weight of passenger trains *five pounds* out of one hundred is paying weight.

These examples are averages from 23,000 miles of our best managed roads. The reports of those comprising the remaining 29,000 miles give no means of ascertaining the averages in these respects, nor even any indication that the subject of dead weights even attracted the attention of the management.

On those great well-managed lines the *Service mileage* is in some cases as low as *three per cent.* of the entire train mileage, while on some roads it is *seven* (7), *eight* (8), 12, 15, and in one case upwards of 20 per cent.

How this affects the interests of stockholders, they can comprehend, and after what has preceded it may easily be inferred how it operates on those of the people.

I do not suppose the most sanguine believer in the perfection of what is, supposes we more than begin to understand the most advantageous modes of constructing and operating railroads.

That great and beneficial changes in our present modes rendering the system more *priable* may be made, I think, will hardly be doubted. That these changes ought to be made, in the fullest light of practical experience is evident.

That such records of the workings of existing railroads could be kept and such reports made as would soon give all this light of experience, who doubts? That for the sake of the public, the people locally, the bondholders, the stockholders, and managers of the roads, these accounts ought to be kept and such reports made, can there be any question?

To overcome the obstacles to this, which will arise from ignorance, conceit, false conservatism, indolence, knavery and "pure cussedness" will doubtless require the interposition of public law. The States may and should require of all railroad corporations under their control the publication quarterly or semi-annually in two or three leading papers in the State, duly attested and authenticated reports, which besides clear statements of financial condition should contain the following named heads and details of *operations, earnings, and expenses*, viz.:

Operations.

1. Line operated—length.
   Branches "
   Sidings "
2. Equipment.
   Engines, No. of,
   Tenders, No. of,
   Baggage cars, No. of,
   Passengers " "
   Sleeping " "
   Freight, different kinds.
3. Train mileage of.
   Passenger trains,
   Freight trains,
   Service trains.
4. Dead weight.
   Average No. passenger cars per train,
   " weight of train,
   " No. of passengers per train,
   " weight per passenger,
   " No. of cars per freight train,
   " weight of freight train,
   " tons of freight per train,
   " percentage of pay freight to entire weight.
5. Car mileage.
   Passenger cars, miles run,
   Average per car,
   Baggage cars, miles run,
   Average per car,
   Sleepers " miles run,
   Average per car,
   Freight " miles run,
   Average per car.
6. Haulage.
   Passengers carried,
   Total miles of travel,
   Average journey,
   Average charge per mile,
   Freight tons carried,
   Total miles hauled,
   Average haul,
   Average charge per mile.

MISCELLANEOUS.

Earnings.

1. From Passengers.
   Through,
   Way,
2. Freights.
   Through,
   Way,
   Special.

3. Mails, etc.
   Miscellaneous,
   Towage of cars, etc.

Expenses.

1. Maintenance of permanent way.
   Iron,
   Ties,
   Bridges,
   Earth work,
   Telegraph lines,
   Buildings.
2. Maintenance of rolling stock.
   Engines,
   Tenders,
   Baggage cars.
   Passenger "
   Sleepers "
   Freight "
3. Fuel.
   Coal,
   Wood.
4. Transportation.
   Engineers' wages.
   Conductors' "
   Trainmen's "
   Station men's "
   Agents' and others' wages
   Lightage, oil, waste, etc.
6. Administrations.
   Officers' salaries,
   Offices.
   Stationery.
7. Incidental expenses.
   Taxes, Insurance, etc.
8. Improvements.
   Permanent way,
   Engines,
   Cars,
   Buildings,
   Real estate,
   Tools and machinery.

Railroad business men more conversant with details will doubtless be able to suggest additional particulars, but a report of the foregoing would reach those *elements* of *wear* and *cost*, most invariable, *train mileage, car mileage, service* and *dead weight.*

Should this succeed in attracting attention to the subject and through the press, State executives and legislators lead to the requirement by law of such reports from Railroad Companies, due from them alike to their own interests and those of the public, I shall have done more good by it than usually falls to the lot of one man to effect in a lifetime.

BLAST FURNACES.

(*Continued from page* 460.)

(24.)—BEYOND A CERTAIN HEIGHT THE TEMPERATURE OF THE GAS AT THE MOUTH NO LONGER DIMINISHES BY REASON OF THE INCREASE OF THE OXIDE OF CARBON.

It is known that the gaseous current of blast furnaces, which is at first composed only of nitrogen and oxide of carbon, becomes charged, as it rises, with increasing quantities of carbonic acid, and even with vapor of water when the mineral and the combustible are moist or chemically hydrated. The reducing action of the oxide of carbon is then partially neutralized in the upper regions of the furnace, and we conceive that a certain mixture of C O, CO^2 and H O remains without action upon the oxide of iron. Thus M. Debray has shown that the peroxide is simply transformed, at an intense red heat, into protoxide, by a mixture of equal volumes of C O and $C O^2$; and that a like mixture brings the metallic iron to the same degree of oxidation. Mr. Bell has verified this double reaction. The mixture corresponds to the ratio (in weight)

$$m = \frac{C O^2}{C O} = \frac{1.529}{0.967} = 1.581.$$

When the carbonic acid has reached this ratio the reduction cannot pass the protoxide; and if the gaseous current also contains the vapor of water, the reduction will cease even before the ratio m attains the value 1.581.

Further, there must be a certain time for the action of the mixture, in order to reduce the mineral into fragments, while the temperature is not very high.

The minerals remain but a short time in the upper part of the furnace, consequently they are but slightly modified by the gases, while the carbonic acid is abundant. Bell has shown that in the furnaces at Cleveland, where the value of m varies between 0.50 and 0.70, the reduction is almost zero near

the mouth. At the temperature of fusion of zinc (near 417 deg.), when the gases contain 31 volumes of $C O^2$ to 100 of C O, corresponding to a value of $m = 0.49$, there are necessary:

5 hrs. to take from the mineral $\frac{1}{5}$ per cent. of the oxygen.
10½ hrs. to take from the mineral $\frac{2}{5}$ per cent. of the oxygen.

And when the gases are composed of 50 vols. of $C O^2$ to 100 of C O, giving $m = 0.79$, not even 0.9 per cent. of the total oxygen can be withdrawn in 5½ hours.

We see, then, that even when the gases are dry and hot, as in the Cleveland furnaces, the reduction at the level of the mouth is really insignificant, and *a fortiori*, it should be so where the minerals are more or less hydrated or carbonated. This fact has been long recognized by Ebelmen and Tunner. Tunner has shown that the reduction commences when the ratio $\frac{C O^2}{C O}$ is near 2, but that the metallic iron appears only when m reaches 0.70, about 23 ft. below the mouth.

Nevertheless it is certain that if, in the upper regions of the furnace, there is no other reaction than the partial reduction of the mineral by C O—a reduction which acts almost without change of temperature—there should be a real advantage in increasing the height of furnaces, as long as the gases about the mouth are at a temperature of about 300 to 400 deg. It is certain that in this way a more complete cooling of the gases is effected, and consequently a better utilization of the heat produced. But it is another reaction that is always produced in the upper portions of blast furnaces, viz., that of the decomposition of oxide of carbon. Now it is precisely this transformation of $2\ C\ O$ into $C O^2 + C$, which accounts for the fact, that after a certain limit the temperature of the gas cannot be sensibly diminished, notwithstanding the increase in height of the furnaces.

Bell first called attention to this singular reaction of minerals upon the gases of blast furnaces, and I have since studied with some care the principal phenomena. The results have been communicated to the Academy of Sciences; the memoir appeared in the May number (1872) of "Annales de Physique et de Chimie." I transcribe the conclusions:

1. If oxide of carbon is passed over iron ore at a temperature of 300 to 400 deg., the oxide of iron is gradually reduced, beginning at the external surface of each fragment. As soon as any portion of the external crust is brought to the metallic condition, the ore splits in all directions, swells, and is covered with pulverulent carbon. This reaction occurs, whatever the mode of preparation of the oxide of carbon.

2. As the reduction approaches its term the carbon deposit becomes less abundant, and would cease from the time when the oxide of iron is completely reduced, if this *absolute* reduction could be realized in the conditions. In every case a very long time would be necessary for this.

3. When the oxide of carbon is added to the metallic iron at 300 deg. to 400 deg., the iron is also covered with pulverulent carbon, while the reducing action of the oxide of carbon is partially *tempered*, either by the presence of a small proportion of carbonic acid, or by that of some source of oxygen that can change into carbonic oxide a small part of oxide of carbon.

4. The oxide of carbon, pure and dry, gives to the metallic iron so much less carbon that this last will be more entirely free from every mixture of oxide; so that the reaction at 300 deg. to 400 deg. would probably be zero, if the experiment could be made upon iron absolutely free from oxide.

5. The carbon deposited either on ore or iron when the oxide of carbon acts with a small proportion of carbonic acid, is a kind of ferruginous carbon, a true compound of carbon and iron, containing at the maximum 5 to 7 per cent. of metallic iron. This carbon differs from that of steel and of hexagonal graphite.

Finally the ferruginous carbon also contains a small portion of oxidized iron, mostly magnetic.

6. The carbonic acid acts as an oxidizer upon the iron. But at 300 deg. to 400 deg. the action is not intense. Only small variable proportions are produced of peroxide, magnetic oxide and protoxide of iron, and these are never attended by a deposit of carbon.

7. The formation of ferruginous carbon is the result of decomposition of the oxide of carbon; $2\ C O$ is transformed in $C O^2 + C$; but this reaction in the last analysis is never directly produced. That it may occur, the simultaneous presence of the metallic iron and of the protoxide of iron is neces-

sary; the one to fix the carbon, the other to retain the oxygen for a moment.

But this re-oxidation of the protoxide, which hinders the final reduction, can happen only when the reducing action of the oxide of carbon is partially tempered by the carbonic acid. This is the *sine qua non* of deposition of carbon. This double reaction is expressed in the formulas

$$3\,Fe\,O + C\,O = Fe^3\,O^4 + \text{(this carbon being united to the iron)}.$$

$$Fe^3\,O^4 + C\,O = 3\,Fe\,O + C\,O^2$$

and so on indefinitely, provided that the oxide of carbon is always tempered by a proportion of carbonic acid.

In a word, the pure oxide of carbon is not decomposed by the iron absolutely free from every oxide element. The carbonic acid, acting alone on the iron, does not furnish more ferruginous carbon. The two gases recombined, if the oxide of carbon is in excess, produce an abundance of ferruginous carbon, by their simultaneous action on the metallic iron at the low temperature of 300 to 400 deg. C.

The spathic iron or the protoxide of iron is rapidly transformed into magnetic oxide by the action of the carbonic acid, without carbon deposit; while the oxide of carbon, under the same conditions, promptly makes an abundant deposit.

9. If the temperature is raised to bright red, the deposit ceases: that already made is burned; at least if in presence of a sufficient quantity of oxide not reduced. The reactions at 300 to 400 deg. and at red heat are altogether different.

10. With regard to blast furnaces, it is to be remarked that the carbon is deposited on the ore in the upper portion of the furnace; and that, by its intimate union with the oxide of iron, it facilitates its final reduction, and also that of the carbonic acid in the middle region. In every case the carbon deposited is again burned before reaching the zone of fusion.

11. The decomposition of the oxide of carbon is attended with heat. To each unit of carbon corresponds a disengagement of 3,134 heat-units.

The decomposition does not continue when a mixture of equal volumes of C O and $C\,O^2$ acts upon the oxide of iron:—*i. e.* when $m = 1.581$. Then, according to Debray, protoxide of iron only is formed, while the metallic iron is necessary to induce the deposit. But if two vols. of C O to one of $C\,O^2$ are taken, corresponding to $m = 0.79$,—then the carbon begins to be deposited, because the metallic iron then tends to appear, provided the current is rapid enough to carry off without hindrance the carbonic acid formed.

With reference to the 3,134 heat-units, here is the essential point of the phenomenon in question. The heat produced by the combustion proper of 2 C and 2 C O is $2 \times 2473 = 4946$ heat-units. When the half of 2 C is transformed to $C\,O^2$ the heat is 8080 h. u.: then the change of 2 C O into $C + C\,O^2$ sets at liberty 8080—4946 = 3134 h. u.

We may conclude that when the gas at the mouth has a temperature of 300 to 400 deg. and a composition $\frac{CO^2}{CO}$ such that is a little less than 0.80, there ensues not only partial reduction, but impregnation and deposit of carbon with marked degradation of heat, resulting in a kind of stationary condition, without final cooling of the gases in spite of the greater height of the furnace.

This is the real progress of phenomena. In the upper regions two different reactions go on at the same time: first, the ore is reduced by C O yielding $C\,O^2$ without sensible change of temperature; again, 2 C O is changed to $C + C\,O^2$ with generation of 3,134 heats units. The carbon C is restored to the charge in a pulverulent form; it descends and forms oxide of carbon in the warmer region below. The gas C O, so reproduced, arises again, and is in its turn decomposed into $\frac{1}{2}\,C + \frac{1}{2}\,C\,O^2$. The same reaction is indefinitely continued, so that the final result is the same as if the primitive 2 C O were directly transformed into $2\,C\,O^2$ by the oxygen of the mineral, *i. e.* as if the reduction had been according to the *ideal* action, by the oxide of carbon without consumption of solid carbon, and therefore without sensible change of temperature.

The decomposition of the oxide of carbon therefore approaches the *ideal* action, and everything favoring this reduces consumption; whence it might be inferred that the indefinite increase of height of furnaces would cause a gradual diminution of consumption, whose extreme limit would be that of *ideal* action.

But the height is limited by the increasing resistance of charges to the blast. And, though the total amount of the heat disengaged depends for a given consumption only

on the value of m, still its *distribution* would be regulated by the mode of production of carbonic acid. When 2 C O gives C O^2, then is heat produced above and cooling in the middle, where the carbon deposit is retransformed into C O by the oxygen of the ore. Below there is a simple *displacement* of heat; but the gases, reheated above, yield less heat to the bed of fusion than if their temperature had been again raised in the middle region, by the direct change of C O into C O^2.

The increase of height thus tends to produce a kind of *constant* calorific condition as a limit.

All just said applies to blast furnaces treating only calcined or anhydrated ores. In furnaces treating hydrated or imperfectly calcined ores the mouth is much colder. At Eisenerz the metallic iron and the decomposition of C O did not begin before about 23 feet of depth. In low furnaces the charges will soon reach the very warm zone where this reaction again ceases. Every increase of height then, as in the previous cases, enlarges the zone where decomposition occurs, and tends to economy by making the gases rich in C O^2. Still, as in the case above, there are limits beyond which the saving would be insignificant.

En résumé—Beyond a certain height, varying with the ore and the profile, there is no advantage in increasing the volume of blast-furnaces.

(25.)—INFLUENCE OF THE SUPERHEATED BLAST.

Let us consider the effect of variations of temperature. Compare the two Consett furnaces cited in the table in (21).

The dimensions and profiles differ but little; the charges and the run are the same; but the temperatures of the blast are 454.5 deg. and 718 deg. respectively; hence the difference of results must be due to this difference in temperature. The blast of the first furnace is heated in the ordinary cast-iron apparatus, that of the second in that of Whitwell-Siemens brick. The fuel for heating the blast is in both cases the gases of the blast furnace.

The first noticeable fact is that the mouth is cold in the ratio that the blast is hot; 477 deg. for 454.5 deg. of blast, and 248 deg. for blast of 718 deg. This is the well known effect of substitution of hot for cold blast. The hot air cools the top of the furnaces, because a greater fraction of the heat *received* is due to the blast. The combustion furnishes a less quantity of gases, and they cool more in traversing the same mass of solid matter.

In this respect the differences of blast-furnaces are great.

The furnace with superheated blast receives per kil. of product only..... 3.751 k. of blast.
And furnishes only..... 5.161 of gas.
While the furnace with ordinary blast receives..... 5.071 k. of blast.
And produces ..... 6.706 of gas.

The heat of combustion in the zone of tuyeres is only 1672 h. u. in the first case, as against 2249 in the second, and this enormous difference is only in a slight degree compensated by the heat furnished by the blast which reaches 643, as against 551 h. u. The zone of fusion of the furnace with ordinary hot blast receives notwithstanding an excess of heat of

$$2800 - 2315 = 485 \text{ h. u.}$$

and the difference between *total* heat received is still more, being

$$4192 - 3654 = 538 \text{ h. u.}$$

Now this excess of heat received by the ordinary furnace consists almost entirely of the heat taken off by the gases, which is

785 h. u. in the first
303 in the second (superheated),

giving difference 455.

The advantages of the second are due to the higher value of $\frac{C O^2}{C O} = m$, which is 0.623 instead of 0.502. The burning of carbon is more useful; which is due to the fact that the lower temperature of the zone of reduction tends to cause a more active decomposition of the oxide of carbon.

The superheated blast at Consett gives a saving of 1.0055 k.—0.789 = 0.2165 k. of pure carbon (per kilo. of run.); an economy only slightly due to the heat directly supplied by the hot blast. It is rather due to the more useful distribution of the heat, causing a more active cooling of the gases, and a more rapid combustion of carbon, developing 3816 h. u. per kilog. in the case of the superheated blast as against 362 in the case of the ordinary hot blast.

Thus the advantages of high heating of the blast are considerable; and this without change in the nature of the products obtained, at least in the case of ordinary ores.

Is there any other limit than that of practical possibility? Can the blast be heated to 800 deg., 900 deg. and 1,000 deg.,

etc., and will each increase of temperature be attended with an equivalent reduction in carbon consumed? Experience only can answer. But with known data, up to a certain point, an account can be given of what would happen if the air in tuyeres were subjected to a greater heat.

The temperature at the mouth diminishes as the blast is made hotter; a fact universally attested. The hot blast acts in the same way as an increase of height; but the decomposition of the oxide of carbon opposes a limit to this refrigeration.

From results with the highest furnaces at Cleveland it seems that the temperature at the mouth cannot become much less than 200 deg. C. (We are considering cases fed by calcined minerals.) At the highest furnace the temperature is 191 deg. C; and in this case the charge is of minerals which have been transported 65 kilometres after their calcination, with consequent absorption of moisture.

Another consequence of the use of very hot air is the gradual increase of the value of m, which at Consett rose from 0.502 to 0.623. The hotter the blast the less carbon burned at the level of the tuyeres; hence the amount of CO here consumed, diminishes. As the oxygen of the ore is constant, one or two things will happen. Either the carbonic acid will go on increasing, and the limit will be reached at which the oxide of carbon will not decompose when $m = 0.80$, the *ideal* m being 1.217, or the excess of CO^2 in the region of reduction. In general the two effects will rather be simultaneous; m will increase together with the carbon consumed in the zone of reduction. Comparing the two Consett furnaces we not only find m rising from 0.502 to 0.623 (in the ordinary blast and superheated blast); but the carbon increases from 0.096 to 0.113. It is easy to calculate from data the proper temperature of the blast and the carbon burned by carbonic acid in the zone of reduction.

Suppose m constant and $= 0.623$, as at Consett, where the blast is 718 deg. The carbon consumed at the level of the tuyeres is 0.789 k. − 0.113 = 0.676 k. Suppose this reduced to 0.650 and 0.600. The total oxygen supplied is known; being composed of the oxygen from fusion and that from the blast. This amount is equal to the total oxygen of the oxide of carbon and of the carbonic oxide, *i. e.*,

$$= \tfrac{4}{7} y + \tfrac{8}{11} m y.$$

The oxygen from fusion is [see (7)]

$$d = \tfrac{8}{3} b - \tfrac{1}{7} (3.03).$$

The last term is composed of two parts: the oxygen disengaged in the zone of reduction

$$= \tfrac{1}{7} (2.82) = 0.403 \text{ k.};$$

and that disengaged about the tuyeres by the direct action of the carbon

$$= \tfrac{1}{7} (0.21) = 0.030 \text{ k.}$$

The oxygen from the blast is determined by the carbon burned at the tuyeres. One of carbon combines with $\frac{4}{3}$ of oxygen to form oxide of carbon; if then the weight of carbon is 0.650 k. we shall have for the corresponding oxygen

$$\tfrac{4}{3} \times 0.650 = 0.867 \text{ k.},$$

of which 0.30 are from fusion and 0.837 from blast.

Let us take the case of the Consett furnace No. 4, in which the carbon from the limestone.

$$b = 0.0485 \text{ k.}$$

We shall have for total oxygen

$$0.867 + 0.403 + \tfrac{8}{3} (0.0485) = 1.399 \text{ k.}$$
$$\therefore \tfrac{4}{7} y + \tfrac{8}{11} m y = 1.399$$

and as $m = 0.623$

$$(\tfrac{4}{7} + \tfrac{8}{11} \times 0.623)\, y = 1.399$$
$$\therefore \text{C O} = y = 1.365 \text{ k.}$$
$$\text{C O}^2 = m\, y = 0.850.$$

The oxide of carbon contains $\frac{3}{7}$ × 1.365 = 0.585 k. of carb.
The carbonic acid contains $\frac{3}{11}$ × 0.850 = 0.232 " "

Total carbon of gas $p = 0.817$ " "

The carbon burned at the tuyeres and that furnished by limestone is 0,650 + 0.0485=..... 0.6985 k.
∴ The carbon burned in the zone of reduction is ..... 0.1185 k.

From the total carbon we deduce the heat of combustion.

The oxide of carbon generates 0.585 × 2473=..... 1446 h. u.
The carbonic acid from the coke (0.262 − 0.0485) × 8080 = 0.1838 × 8080=..... 1483 h. u.

Total ..... 2929 h. u.

Assuming that the absorbed heat is the 3654 (as before shown) the blast would have to furnish 725 h. u. instead of 643.

But in fact the heat absorbed would be less because the weight of the gas is less, and the temperature would be slightly diminished. We find a maximum value by assuming the limit of 200 deg.

The weight of the gas is as follows:

$m\,y = C\,O^2 =$	0.8350 k.
$y = C\,O =$	1.365
Nitrogen $3.33 \times 0.837 \times 0.97677 =$	2.722
Weight of dry gases	4.937
Water from coke	0.022
Weight of humid gases	4.959 instead of 5.161 as in (20) *ante*.

The heat carried off by the gas is

$$4.959 \times 200° \times 0.237 = 235 \text{ h. u.}$$

instead of 303 as in (20). The absorbed or necessary heat would be diminished by 68 h. u. to 3586 h. u.

Assume this figure, though rather low, because the gas leaves the furnace at a temperature a little above 200 deg.

The blast would have to furnish at least $3586 - 2929 = 657$ h. u.; and as the weight of the blast is

$$0.837 \times 4.33 \times 0.9828 = 3.562 \text{ k.}$$

the minimum temperature is

$$\frac{657}{3.562 \times 0.239} = 772°.$$

The heat developed in the zone of reduction is equal to the total heat of combustion, 2929 h. u. less than that about the tuyeres generated by the combustion of 0.650 k. of carbon; *i. e.*,

0.650 k. $\times$ 2473 =	1607 h. u.
And for heat in zone of reduction	1322
Total	2929

The heat of combustion in the reduction zone of No. 4, Consett, is 1339 h. u. So, as the temperature of the blast rises, that of reduction lowers, notwithstanding the increase of carbon consumed in that region, *i. e.*, from 0.113 to 0.1185 k.

Let us apply the same calculation to the carbon burned about the tuyeres, which is reduced to 0.600 k. The corresponding oxygen is $\frac{4}{3} \times 0.600 = 0.800$ k.; and as 0.030 are due to fusion, there remains for the blast 0.770 k., and therefore the total oxygen is

$$0.800 + 0.403 + \tfrac{5}{3}(0.0485) = 1.332.$$

$$\therefore C\,O = y = \frac{77 \times 1.332}{78.088} = 1.300 \text{ containing} \ldots\ldots 0.557 \text{ k. of car.}$$

$C\,O^2 = m\,y = 1.300 \times 0.623 = 0.810$ containing	0.221
Total	0.778
Carbon burned at the tuyeres and furnished by limestone	0.6485
Carbon consumed in zone of reduction	0.1295

The heat of combustion is

by C O. 0.557×2473	1377 h. u.
by $C\,O^2$ $(0.221 - 0.0485) \times 8080 = 0.1825 \times 8080 =$	1394 "
Total	2771 "

To determine the *necessary* heat.

The gases are composed of

$C\,O^2 = m\,y =$	0.810 k.
$C\,O = y =$	1.300
Nitrogen $= 3.33 \times 0.770 \times 0.97677 =$	2.504
Weight of dry gases =	4.614
Water from coke =	0.021
Weight of moist gases =	4.635

Hence the heat taken off by gases is

$$4.635 \times 200° \times 0.237 = 221 \text{ h. u.}$$

instead of 303 as in (20) *ante*. The necessary heat is reduced 83 h. u., to 3571. The blast must therefore furnish $3571 - 2771 = 800$. But the weight of the blast is

$$0.770 \times 433 \times 0.9828 = 3.277 \text{ k.;}$$

hence

$$\frac{800}{3.277 \times 0.239} = 1022°.$$

To determine the heat generated in the zone of reduction,

Total heat of combustion	2771 h. u.
Heat at tuyeres $0.600 \times 2473 =$	1484 "
	1287 "

We give in the annexed table, with the data of actual working of the Consett furnace No. 4, the results obtained under hypothesis of the constancy of the ratio $m = 0.623$. (See Table I., p. 554.)

We perceive that beyond a certain limit of temperature the advantages of superheated air become less and less; a fact due to several causes.

1. The amount of blast diminishes as the temperature rises.

2. The cooling at the mouth, at first very rapid, is afterwards limited by the greater decomposition of the oxide of carbon.

3. The ratio m, supposed constant from 718 deg., cannot pass a certain maximum, which limits the amount of heat generated in the zone of reduction. It follows, that though in case of the furnaces at Cleveland there was great advantage in increasing the temperature of the blast from 400 deg. to 700 deg. there would not be a corresponding advantage in heating to 1000 deg.

We now show that these conclusions would be but little modified if m should

TABLE I.

	kilog.	kilog.	kilog.
Carbon burned at tuyeres	0.676	0.650	0.600
Carbon burned in reduction zone	0.113	0 1185	0.1295
Total carbon consumed, including that from iron	0.819	0.7985	0.7595
	h. u.	h. u.	h. u.
Heat generated in zone of reduction	1339	1322	1287
Heat generated about tuyeres	1672	1607	1484
Total heat of combustion	3011	2929	2771
Heat from blast	643	657	800
Total or necessary heat	3654	3586	3571
	deg.	deg.	deg.
Temperature of gases	248	200	200
" " blast	718	772	1,012
	kilog.	kilog.	kilog.
Weight of blast	3.751	3.562	3.277

reach the value 0.70, or even 0.80, the point at which the oxide of carbon ceases to decompose.

[The writer makes calculations as above, for Consett furnace No. 4, and tabulates the results for $m = 0.70$, and $m = 0.80$, the temperature at mouth as before limited to 200 deg.]

TABLE II. For $m = 0.70$.

	kilog.	kilog.	kilog.
Carbon burned at tuyeres	0.676	0 650	0.600
Carbon burned in reduction zone	0.0965	0 1035	0.1145
Total carbon consumed, including that from iron	0.8025	0.7835	0.7445
	h. u.	h. u.	h. u.
Heat generated in zone of reduction	1385	1369	1329
Heat generated about tuyeres	1672	1607	1484
Total heat of combustion	3057	2976	2813
Heat from blast	594	609	757
Total or necessary heat	3651	3585	3570
	deg.	deg.	deg.
Temperature of gases	248	200	200
" " blast	662	715	967
	kilog.	kilog.	kilog.
Weight of blast	3.751	3.562	3277

TABLE III. For $m = 0.80$.

	kilog.	kilog.	kilog.
Carbon burned at tuyeres	0.676	0.650	0.600
Carbon burned in reduction zone	0.0785	0.0865	0.0985
Total carbon consumed, including that from iron	0.7845	0.7665	0.7285
	h. u.	h. u.	h u.
Heat generated from zone of reduction	1442	1428	1384
Heat generated about tuyeres	1672	1607	1484
Total heat of combustion	3114	3035	2868
Heat from blast	477	549	701
Total or necessary heat	3591	3584	3 569
	deg.	deg.	deg.
Temperature of gases	200	200	200
" " blast	561	645	895
	kilog.	kilog.	kilog.
Weight of blast	3.751	3.562	3.277

For the same value of m the carbon consumed in the reduction zone increases, while the total consumption tends to diminish; yet the heat generated in the reducing zone is less as the blast is hotter. Comparing the three tables we see that to reach the *necessary* heat the blast should increase in heat as m diminishes; and it is obvious that it would be more economical to attain this *necessary* heat by a proper disposition of the furnace than by a superheated blast. In every case the maximum of economy is realized by the concurrence of a very hot blast and of a high value of the ratio m. But this value corresponds to a certain mean height, as before shown, and supposes an action slower in proportion to the increase of volume, at least beyond a certain limit.

Finally, as to the question whether there is advantage in a temperature of 800, 900, or 1000 deg., we can hardly answer in the affirmative. Economy diminishes rapidly with each increase of temperature; so that it does not seem worth while to exceed 700 deg. or 800 deg.

CONCLUSIONS.

1. The production of large furnaces beyond 200 c. m. does not increase in the ratio of their volumes.

2. To estimate the action of furnaces, it is well to determine the ratio $\frac{CO}{CO^2}$ at the mouth. With this not only can the actual composition of the gases be found, but also the quantity of air demanded by the blast furnace.

3. To determine the ratio $\frac{CO^2}{CO}$ it is not sufficient to take a certain number of *instantaneous* samples; but the gas must be drawn off during several hours.

4. The composition of the gas once known, the relation between the heat *received* and that *expended* should be known; and a separate account should be taken of the heat generated in the zone of the tuyeres, and in the zone of reduction.

5. Applying these principles to some of the Cleveland furnaces, we can show that the advantages of high furnaces result simply from the lower temperature in the upper part of the shaft. The reduction here is more complete, by means of the sole action of oxide of carbon, without solid carbon; the *ideal* action is approximated, which supposes the solid carbon to be burned exclusively by the oxygen of the blast. An accessory advantage, but more direct, is due to the lower sensible heat at the mouth.

6. Consumption depends in part on production. The minimum corresponds to a mean velocity, which varies with the height and volume.

7. Because of the decomposition of carbon in the upper part of the furnace, the temperature of the gas at the mouth cannot pass below a certain limit, and in this respect there is no advantage, when this limit is reached, in increasing the volume. Too slow action and an excess of volume may be a disadvantage.

8. The heat from the blast replaces with advantage that developed in the zone of the tuyeres. The relative economy, due to the hot blast, decreases as the temperature is increased. In practice, actual economy in little beyond 700 deg. to 800 deg. The hot blast tends to raise the ratio $\frac{CO^2}{CO}$, and by the cooling of the upper regions, it favors the reduction without consumption of solid carbon; in other words, the *ideal* action.

(27.)—APPLICATION OF THE NEW METHOD OF ANALYSIS TO A FRENCH BLAST FURNACE.

* * * * * * * I shall attempt to show, by an example, how it is possible to show, even without chemical analysis, how far the action of a blast furnace approaches toward or deviates from the *ideal* work, *i. e.*, the minimum of consumption.

We have seen above that the old blast furnaces at Cleveland, 14 to 16 m. high, were far from realizing this *ideal* work. The gases escaped at a high temperature and the proportion of carbonic acid was not large, $\frac{CO^2}{CO}$ seldom reached 0.40. The increase in height helped in both respects; still it is evident that when the gases are cold and $\frac{CO^2}{CO}$ is near unity, increase in height would be useless; hence the advantage of determining $\frac{CO^2}{CO}$ for each case. By this means we can find out *a priori* whether there will be any gain in modification of dimensions.

There are in France many coke furnaces with consumption not greater than that of the large Cleveland furnaces; and still the ores are not richer nor more fusible than those of the north of England. Little would

be gained by increasing their height, for the gases are relatively cold and the consumption not greatly increased, so that we are assured *a priori* that $\frac{CO^2}{CO}$ is not far from unity.

The example is that of one of the Pouzin blast furnaces, on the Rhone, between Valencia and Montelimart. The data are of 1857; but ores, coke, consumption, etc., remain as then; the production only having changed, being 18 tons in 1857, and 25 to 30 tons at present.

The profile was slender (élancé); height, 16.90 m.; volume 115 m. The blast was heated to 290 deg.; the temperature at the mouth 250 deg. The product was forge No. 4. The ore was red hematite. The composition was

Peroxide of iron	60 with 42 of iron.
Clay	21
Carbonate of lime	15
Water	4
	100

The elements of the work of the furnace are presented in the following table, which gives the *balance* of raw materials and products.

TABLE IV.

Elements per Kilogram of Product.	Distribution.	Products. Run.	Slag.	Gas.
		kilog.	kilog.	kilog.
Ore 2.340				
Composed of:	Kilog.			
	Peroxide of iron 1.343 { Fe	0.940	....	....
	{ O	....	..	0.403
(0.60) $Fe^2 O^3$ 1.404	Peroxide of iron 0.061 { Fe O	....	0.055	....
	1.404 { O	....	....	0.006
	0.060 Silica and reduced { Si, etc.	0.030	....	....
(0.21) Clay 0.491	earths { O	.. ..	....	0.030
	(See § 7.)			
	0.431 clay not decomposed.	....	0.431	....
(0.15) Carbonate of lime 0.351	Lime	....	0.196	....
	CO^2	....	....	0.155
(0.04) Water 0.094	Steam	....	....	0.094
Ore 2.340				
Limestone flux 0.600	Lime	....	0.336	...
	CO^2	....	....	0.264
	Carbon ..... 0.970 k.	0.030	....	0.940
	Ash (0.15) ..... 0.180 k.	....	0.180	....
Coke 1.200	Water ..... 0.050 k.	....	....	0.050
	Coke ..... 1.200 k.			
Total of solids 4.146	.....	1.000	1.198	1.942

NOTE.—Allowance is made in this table for 3 per cent. of carbon, 2 per cent. of silicium and 1 per cent. of foreign matter To obtain the total weight of the gas, we must add to 1.942, the weight of air injected. This is approximately 4.875 k.

To determine by this table the actual working of the furnace we must determine approximately the *heat consumed*. This consists of four parts: two to be rigorously determined; the other two, approximately.

The *first* includes the heat absorbed by reduction, varying with the ores of peroxides; the other that of the run on leaving the furnace. They are respectively 1984, and 310 heat units.

The *second* is the heat taken by the slag. I assume 500 h. u. per kilog. of slag instead of 550, giving for 1198 of slag, 599 h. u. Also, that of the decomposition of the limestone, the vaporization of water, and the decomposition of the moisture of the air. The last element is a little uncertain. Assume a weight of 4.50 kil.; reference being had to the case of the Cleveland furnaces.

The *third* is the heat carried off by the

gases. Their weight is the injected air *plus* the gases from fusion, *i. e.*, $4.5 + 1.942 = 6.442$ kil.

The *fourth* is the heat lost by the walls. Assume 300 heat units for this.

With these data the Pouzin furnace gives the following results:

	h. u.
1. Heat of reduction and fusion	2294
2. Heat taken by slag $1.198 \times 500 =$	599
Heat absorbed by limestone of ore and flux $0.951 \times 373.5 =$	355
Heat absorbed by vaporization of water of ore and coke $0.144 \times 606 =$	87
Heat taken up by decomposition of moisture and of blast $0.0062 \times 4.5 \times 3.222 =$	90
3. Heat carried off by gases $6.442 \times 150 \times 0.237 =$	229
4. Heat lost by walls	300
Total consumed or *necessary* heat	3954

Assuming for weight of blast 4.50 k., we have for approximate value of heat from blast

$$4.50 \times 290^c \times 0.239 = 212.$$

Hence for heat of combustion we have 3642 h. u., while the total calorific power of the carbon burned is

$$0.940 \text{ k.} \times 8080 = 7595 \text{ h. u.}$$

giving for heat developed in the furnace

$$\frac{3642}{7595} = 0.48$$

as calorific power of the carbon burned; the exact ratio found for the large furnace at the Clarence Works (17 *ante*). This shows that this furnace, notwithstanding its small capacity, was in good working condition.

It is easy to find from the carbon burned and the heat generated the values of $\frac{C\,O^2}{C\,O} = m$ and $C\,O = y$.

We have

$$\tfrac{3}{7}\, y + \tfrac{3}{11} m y = p$$

and the heat is due to the carbon converted into C O and C O^2,

Formula 4 of (15) *ante* gives

$$\tfrac{3}{7}\, y \times 473 + (\tfrac{3}{11} m y - b)\, 8080 = 3642$$

or

$$(\tfrac{3}{7} \times 2473 + \tfrac{3}{11} m \times 8080)\, y = 3642 + 8080\, b = Q.$$

Combining we get

$$m = \frac{11}{7}\left(\frac{Q - 2473.p}{8080\,p - Q}\right);\quad y = \frac{7}{3}\left(\frac{8080\,p - Q}{5607}\right);$$

and

$$m y = \frac{11}{3}\left(\frac{Q - 2473\,p}{5607}\right).$$

Applying formulas to the Pouzin furnace we obtain

$$b = 0.12 \times 0.951 = 0.114 \text{ k.}$$

$$p = 0.940 \text{ k} + 0.114 \text{ k.} = 1.054 \text{ k.}$$

$$Q = 3642 + 8080 \times 0.114 = 4563 \text{ h. u.}$$

$$m = \frac{11}{7}\left(\frac{4563 - 2606}{8516 - 4563}\right) = \frac{11}{7}\left(\frac{1957}{3953}\right) = \frac{21527}{27671} = 0.78,$$

$$y = 1.645 \text{ k., and } m\,y = 1.280 \text{ k.}$$

The gases contain

1.645 k. of oxide of carbon.
1.280 k. of carbonic acid.

The first gas contains	0.705 k. of carbon.
The second "	0.349
Total	$1.054 = p$.

The formulas of (7) *ante* give the oxygen and nitrogen from the blast. Formula (3) gives for oxygen disengaged by the fusion to the gases,

$$a = \tfrac{8}{3} \times 0.114 + 0.423 = 0.727 \text{ k.}$$

And formula (2) for total oxygen from blast,

$$x = \frac{v}{77}\,(44 + 56m) - 0.727 = 1.146 \text{ k.}$$

Hence for oxygen of *dry* blast

$z = 0.97677\, x =$	1.119 k.
Nitrogen $3.33\, z =$	3.726
Dry air	4.845
Moisture of air $0.0062 \times 4.845 =$	0.030
Weight of humid air	4.875

The gases are composed of

C O^2	1.280 k.
C O	1.645
Nitrogen	3.726
Dry gas	6.651
Water of fusion bed	0.144
Humid gases	6.795

The quantities of blast and gas are a little larger than those assumed *a priori*. But with regard to calorific effect the compensation is almost exact. The excess of blast 0.375 furnishes 25 h. u. more, and the excess of gas 14 or 15 h. u. more than the calculated amount.

There should consequently be an excess of heat furnished amounting to 10 or 11 h. u. which is balanced by a lower heat of combustion: that is, it would be 3632 instead of 3642 h. u. To be exact, new values of m and y could be calculated. The number Q in the preceding formulas would be diminished from 4563 to 4553. This correction would be insignificant; it would increase the value of C O only 0.004 k (1.649 instead of 1.645) at the expense of that of C O^2,

and the value of m would not be affected. In short the preceding figures represent with sufficient exactness the actual condition of matters; and show that the working of the Pouzin furnace is in reality very satisfactory.

The ratio m almost attains the limit 0.80, when the decomposition of the oxide of carbon ceases. The gases are rich in CO^2, and yet cool. In these conditions an increase in height would not produce a sensible effect. The consumption could not be reduced below 0.970 k of pure carbon, by superheating the blast as at Consett. This advantageous working of the Pouzin furnace is, in my opinion, due mostly to its slender profile. The distribution of gas and the reduction are uniform. The director once attempted to increase the height without modifying the method of charging. The working was less regular and the consumption greater. Since that time the production has been increased by increasing the blast, but the consumption has not become less than 0.970 k. of pure carbon.

We see that we can indirectly, even without experimental determination of $\frac{CO^2}{CO}$, obtain an approximate estimate of the mode of combustion of carbon in blast furnaces, and of the relative economy of working. But this indirect determination depends on a more or less hypothetic valuation of the heat consumed. It is always better to determine this ratio by analysis of gases, so as to fix rigorously the amount of heat received.

This is a mode of control of the working of furnaces easy to effect. I recommend it to masters. I indicate the following as reasons for the difference between the working of the furnace just cited and those of the old type at Cleveland:

1. The profile of French furnaces is generally more slender (élancé) than that of the English. Hence there is a better distribution of gases; the reduction takes place in the upper portions, with less consumption of solid carbon. I have already said that to this difference of profile should certainly be attributed in part the economy of the Clarence (1866) furnace as compared with that of Ormesby (1867), and that of the Clarence (1853).

2. In France more attention is given to the mode of charging. The influence of this upon the distribution of gas is well understood. In this way approximation may be made to the *ideal* action.

3. The region of fusion near the tuyeres in English furnaces seems to me to be too large. In the smallest furnaces at Cleveland, the diameter is never less than 1.80 m., and in a large number of 300 to 500 c. m. capacity, it amounts to 2.20, 2.40, 2.50 and 2.75 m.; and this with heights often less than diameters; while in French furnaces the mean diameter is seldom more than 1.50 or 1.60 m. The capacity of the region of fusion has an indirect influence upon consumption. For a refractory metal it is not sufficient that we have a certain amount of heat; it must be well distributed and the local temperature must be intense; which can be the case only in a space sufficiently limited.

Tunner's experiments have shown that, about each tuyere the zone of combustion properly so-called is very limited, and that if we wish an increase of temperature the zone of fusion must be made narrower. Whatever the dimensions, this high temperature cannot be realized, with a relatively small consumption, except by use of narrow and high structures.

THE TAY BRIDGE GIRDERS.

From "The Engineer."

A railway bridge having a total length of nearly two miles, consisting of wrought iron girders, and carrying its moving load at a maximum height of 80 ft. above the surface of the sea, constitutes a prominent progressive feature in the art of engineering construction. The design, both of superstructure and foundations, and the method by which the erection of the bridge has been so successfully carried out, have been fully described and illustrated. It is not our intention to revert to them now, but to consider the more theoretical part of this great engineering work. We allude especially to the form, character, and proportions of the girders. None of them have pretension to what is termed a large span, and the majority of them have dimensions sufficiently limited to offer no scope for either selection or criticism. So long as the

span of a straight girder does not exceed 50 ft. or 60 ft., it is immaterial, with respect to mere economy, what particular form is employed, or what the arrangement of the bracing is. There is no doubt that even in spans of these insignificant proportions, there are certain types of girders which are stronger than others, and therefore preferable to adopt; but the absolute amount of metal will be practically equal in all. This apparent anomaly is due to the fact, that the increase of strength does not result from the amount of material or sectional area, which is constant in the different examples, but from the *ensemble* of the several members of one girder being better adapted than those of another to resist the strains brought upon them, either collectively or individually. This may be exemplified in a simple point of view by the case of struts. If two struts be of equal sectional area, but of different form, the one which has the stiffest form will bear the greatest strain. Thus, the strength of a solid triangular cast-iron pillar is to that of a solid round pillar of the same material as 11 to 10, both pillars having the same length and weight. Again, a hollow cylindrical pillar of cast iron is twice as strong as a pillar of the same weight, shaped like the connecting rod of a steam engine, and 25 per cent. stronger than a similar pillar of the H section. By analogous reasoning it is evident, that although the sectional area of both the web and the flanges in any two examples of girders may be equal, yet the arrangement of the parts may in the one be superior to that in the other, and proportionately increase the strength of the whole combination.

Let us now direct our attention to the main girders of the Tay Bridge, which have a span of 200 ft., and are continuous over four spans; and first let us consider the principle of continuity, concerning which there is a good deal to be said on both sides. The continuous girder is a favorite, with continental engineers, and with all those who believe in that nice adjustment between theory and practice, which the former demonstrates so speciously, and the latter frequently proves to be impossible. That theoretically the principle of continuity in girders possesses many advantages, cannot be for a moment questioned. Neither, at the same time, can it be denied that those advantages are often completely negatived in actual practice. There are many engineers who, to use a common phrase, do not believe in the real economy of continuous girders. Without being converts to their creed, it must be admitted that they have some grounds for their disbelief. The first point essential to the safe adoption of the continuous principle, viz., that of a perfectly sound and unyielding foundation, we will assume exists in the Tay Bridge, and it remains to be discussed whether the general character of the case is one which is likely to derive the full advantage of that system of girder construction. This consists, in the first place, in the smaller amount of material required in the flanges, in comparison with a discontinuous girder of similar span and loading; and in the second, in the shifting or transference of a portion of the dead, or permanent load at the centre, to points nearer the intermediate supports. Evidently the value of this latter condition is in exact proportion to the span of the girder and the fixed load. When the latter is large, the portion of it thus transferred becomes also considerable, and the sectional area, and consequently the weight of the girders, becomes very much reduced. The same result ensues when the permanent or dead load is large in comparison with the live or moving load. In the present example these favorable conditions are absent, as the correct proportion between the two loads is actually reversed. The dead load upon a single girder is 84 tons, and the live 132 tons. A very important practical objection against the adoption of the continuous principle now bears upon the question. Owing to this disproportion between the two loads, the shifting, or the range of the points of contrary flexure, is very great, and the parts of the flanges which are subjected to alternate strains of tension and compression commensurably increased. We do not lay so much stress as many do upon this fact when the material of which the girder is built is wrought iron, but there is no doubt the objection is a valid one. It is true that the same circumstance also occurs in discontinuous girders, but the action of the alternate strains of different character is confined to a few diagonal bars in the web at the centre of the girder—a part where the sectional area of the bars is usually in excess of that required by theory. Moreover, there is no comparison in the amount of the alternate strains in the web of a detached girder, and in the flanges of a continuous one. In the example under

consideration, which will serve to illustrate both cases, since the effect of continuity on the web of a girder is of no consequence, the maximum alternate straining of the diagonals will not exceed 8 tons, whereas in those portions of the flanges subject to the same action it will amount to nearly ten times as much. The point which appears to us open to question is, whether a span of 200 ft. for a single line bridge is sufficient to warrant the adoption of the continuous principle, although there may be a slight saving in the actual weight of metal in consequence.

Deep girders of the open web type are more economical than shallow ones. Experience, and experience alone, has proved this. Some years ago a depth of one-twelfth of the span was considered a large ratio, but lately one-tenth and one-eighth have been arrived at. Trusses of a triangular shape—such as are used in roofs and in timber bridges—are an exception to the rule, which places the ratio of one-eighth as the maximum. The central depth of bow-string girders, which are generally deeper than the straight girders, with one exception, have not exceeded this limit. The exception alluded to is a bridge designed by Brunel, carrying the Great Western Railway over the Thames near Windsor, which has a proportion of span to depth as 7.5 is to 1. In the Tay Bridge girders the chief objection which prevents very deep girders such as they are being usually adopted, is successfully met. This consists in the fact that it becomes difficult to impart sufficient stiffness to the diagonal compression bars in the web when they exceed certain lengths. Mr. Bouch has combated this difficulty by making each of the struts in the web a small girder in itself, the ties being constructed of plain rectangular bars, or rather plates, as their scantlings reach up to 20 in. by $\frac{1}{2}$ in. We are strongly of opinion that it would have been advisable to substitute one or two additional series of triangles in the web, and so have reduced the size of each individual bar. It is difficult to understand how the theoretical assumption of a uniformly distributed load, can be expected to hold good when the points at which the load is applied are 25 ft. apart. Moreover, the local strains at the apices of the triangles must be very considerable. This reasoning applies whether the girders be considered loaded uniformly with only the dead weight, or with the dead and live in conjunction. The elevation of the girders is very similar to that of the Charing Cross Railway Bridge, each having one crossing of the diagonal in the centre of the web. There are, however, no superfluous vertical bars in the Tay girders. So long as there is only one intersection of the bars in the web, it must of necessity be in the centre, but otherwise it is the most unsuitable position for the crossing to occur in. The length of the diagonals in the Tay Bridge, in the girders of 200 ft. span, is upwards of 34 ft., and as there is only one intersection in the web the greatest unbraced length is 17 ft., which is of itself considerable. The subdivision of the total length of the struts into a couple of shorter ones is accomplished by the connection with the intersecting ties, since they are supposed to be kept always in one plane, and consequently to retain the struts in the same. But the ties themselves are of the same total length as the struts, and the important question arises, are the ties always strained to an extent sufficient to enable them to act in this manner? The assumption that there is no cross strain developed at the intersection of the struts and ties in the web is based on the fulfilment of that condition. Unless the ties are maintained in a constant state of tension sufficient to enable them to act as bracings to the struts, the latter are in a very unsatisfactory condition. It must be borne in mind that girders with one intersection of the web are only one remove from the Warren type, which is unsuited to large spans. That the design of the Tay girders is safe both in theory and practice, is apparent on examining the drawings, but it possesses, in consequence of the systems of triangulation in the web being limited to a couple, the disadvantage belonging to its near prototype, of the strains being brought upon the flanges *per saltum*. This is the very objection which the lattice principle removes, insomuch as it affords more or less continuous support to the flanges, and prevents all chance of their being affected by any strains but those which act in a horizontal direction. It is evident that each unsupported portion of the flanges in the Tay girders which is situated between the apices of the triangles, and is 25 ft. in length, except for the small vertical ties and struts, is in exactly the same position as if it were a small girder, and subject to a bending strain as well as one in a horizontal direction.

In girders, as well as in every form of

truss, the primary object of adopting that type of construction must never be lost sight of, which is to insure that the different members shall be subjected to no other strains but such as act in the direction of their respective lengths. In order to give some support to the parts of the flanges—25 ft. in length—situated between the apices of the triangles, vertical ties and struts have been introduced. The former are used when the load is on the lower flange, and extend from the centre of the distance between the apices to the crossing of the bars in the web. When the load is on the upper flange these short verticals are struts, and answer the same purpose as the ties. This is apparently tantamount to transferring a portion of the load to the centre of the girder—the very worst place for it—in addition to bringing a cross strain at the intersection of the bars in the web. Were these short ties and struts intended to act as vertical bars, and constitute an integral portion of the web, they should extend from flange to flange; but as they are introduced merely to prevent the sagging of the long unsupported lengths of the flanges, the greater part of the load is borne by the diagonal bars. At the same time it would have been preferable to carry these vertical bars the whole depth of the girder. As it is, they have some work to do, and the employment of both vertical and diagonal bars in a web is unnecessary. A girder of long span with a light load is, so far as economy is concerned, a more troublesome job to an engineer than one of long span with a heavy load. The noticeable feature in these girders is the large sectional area of the diagonal bars of the web. The depth of the struts is nearly equal to the width of the flange. The ties are double, passing outside the struts, which have solid instead of open bracings between the bars and angle irons of which they are composed. The scantlings of the diagonals, together with the absence of multiple bracing, precluded the use of rolled iron, and built up sections became a necessity. The average weight of the girders having a span of 200 ft., is 45 tons, which is light. To this must be added half the weight of the horizontal diagonal bracing between each pair of girders. In girders of so large a depth as 27 ft., and designed for a single line, which materially reduces their base of stability, this bracing is essential, particularly when the load is on the upper flange. We are not aware whether there is any chance of corrosion of the material from the influence of the sea air taking place; but if so, plates and bars of $\frac{1}{4}$ in. in thickness are useless. Under any circumstances this is fining down the metal too much in the girder work, except for very insignificant examples. While every engineer must have due regard to economy, it must be borne in mind that the first consideration is efficiency.

MAGNETS AND THE BEST MEANS OF INCREASING THEIR EFFICIENCY.*

Translated from "Les Mondes."

At a recent meeting I made known to the Academy the process enabling me to measure the force necessary to detach a contact of iron, always the same, placed upon the different points of a magnet. This force is measured in grammes; I designate it by F. I will tell how it varies at several points of a magnetized plate, straight, long and flat.

Upon the line leading to the middle of this plate parallel to its length, that is to say, the length of its axis, the adhesive force or force of detachment F is null, not only at the middle, but up to a short distance from the two ends; after which it increases rapidly as far as the extremities, where it forms two equal curves, convex with regard to the magnet, and of which Biot has given the equation. It is the same upon every line parallel to the axis, with this difference that the ordinates of the curves are greater towards the edges than at the middle. I have only studied the axial curve; it is of this that exclusive mention will be made in what follows.

For a steel magnetized to saturation, F increases with the thickness of the plate, following laws probably complicated which I have not yet studied; it does not vary sensibly with the breadth. All my experiments have been made with steel springs

* A paper read before the Académie des Sciences by M. J. Jamin.

which have a thickness equal to one millimetre. The laws which I shall make known will probably apply to other thicknesses, with different values for the coefficient.

When two parallel magnetic plates are placed upon each other, the curves which represent the values of F spring up, because the magnetism leaves the faces which are brought in contact in order to take refuge in the exterior parts. At the same time the two curves approach each other and the middle of the magnet. This effect increases with a third plate and with a fourth. Finally the two curves join in the middle. From this moment, the pile has reached its maximum. A greater number of plates changes nothing of its intensity in any point; any addition to the limited number of plates is a dead loss and only a useless waste of steel. This final magnet is the only one capable of a precise definition, and the only one which ought to be employed, since it gives the maximum of effect; I will call it the *normal magnet* or *limited magnet*.

The curve which represents the force F in the normal magnet is then a parabola represented by the equation $F = A\,x^2$, x being the distance to the centre of the plate, and A a coefficient which varies with the length.

It is difficult to say after what number of plates the maximum is attained, since it is reached but slowly; but it is evident that this number is as much greater as the length of the pile is more considerable. There must be 3 or 4 of them for 100 millimetres, 6 to 8 for 200, 9 to 14 for 300. It can be said approximately that this number is proportional to the length of the pile we wish to form.

We will admit with Coulomb that the force of detachment F is proportional to the square of the magnetic intensity in each point, and that the curve of the intensities is a parabola.

The normal pile possesses this remarkable property that the curve of the magnetic intensities reduces itself to a straight line. This simple law shows at once that the pole is at a third of the half-length; it permits us to express the totality of the magnetism of the pile.

When a contact is made with the magnet, all free magnetism disappears if this contact is sufficiently great and contains a sufficient quantity of iron, and the adhesive force is in inverse proportion to the surface of contact.

The force of a plate increases notably with its thickness, but it increases less rapidly than this thickness, so that after a limit it remains stationary; but a plate of any thickness is not as strong as two others of half the thickness, much less powerful than three plates of one third that thickness, and in general the difference increases with the number of plates with which a pile of a given thickness is composed. I have thus been lead to employ steel ribbons, and as they are produced, in abundance and with regularity, of excellent metal, it has sufficed for me to place them upon each other in sufficient number to construct normal magnets and attain the limit of the power while diminishing considerably the weight. It is in this way that I have obtained magnets bearing twenty times their weight.

REPORTS OF ENGINEERS' SOCIETIES.

SOCIETY OF ENGINEERS.—At the ordinary meeting of the Society, held on Monday evening, April 7th, Mr Jabez Church, President, in the chair, a paper was read by Mr. Henry Gore, on "Horse Railways and Tramways." The author commenced by giving a brief sketch of the rise and progress of road making in England, from the time of the Roman invasion down to the period when Telford, McNiel, Macadam, and others, devoted their attention to perfecting our great highways. He then described the early attempts to construct tramways or trollieways in the mining districts, commencing with the wooden railways of the Tyne and Wear, of 1680, and traced the history of this description of roads and the application of iron in their construction, showing also, by reference to documents in the Patent Office, that so early as 1803, the idea was started for constructing street tramways with iron rails. Mr. Gore referred to several Acts of Parliament which were passed at the commencement of the present century, authorizing the construction of horse railways and tramways for general traffic, particularizing the roads between Gloucester and Cheltenham, and that between Stratford-on-Avon and Moreton-in-the-Marsh. Afterwards he described some of the earlier street railways in the United States, and the attempts made by Mr. Train to introduce the system into the metropolis, and pointed out the cause of their failure. Mr. Gore alluded to the tramway he had himself constructed in 1863 at Valparaiso, on the west coast of South America.

Having concluded the historical sketch the author then proceeded to describe the principal features of the various forms of construction adopted in the Street Tramways which have recently been laid. This part of the paper was illustrated by a series of carefully prepared diagrams, embracing all the important details of each type of construction, including the use of concrete, transverse timber sleepers, cast-iron block chairs, and con-

tinuous cast-iron girder rails. After describing each system of construction, the author pointed out the more prominent objections observable in the several types now in use, amongst the chief of which was the employment of concrete, which he held to be highly prejudicial. He showed the effect of vibration in destroying the cohesion of the particles of cement, and the constant tendency there was for the mass to be broken up, and called especial attention to the evils arising from the want of sufficient bearing surface or proper lateral support to maintain the gauge. Mr. Gore advocated the use of transverse sleepers as the best means of distributing the load and neutralizing the effects of vibration, and the importance of thoroughly sound workmanship, both as regards the laying of sleepers and rails and in well consolidating the foundation of the road by ramming and packing. He recommended the use of a species of tar or asphalt concrete as a bed to receive the stone pavement, and also for packing round the timber sleepers. He discountenanced the use of lime or cement concrete as a foundation for tramways, and concluded his interesting paper by urging the use of thoroughly dessicated and prepared timber, so as to insure the greatest possible durability, and a system of paving a roadway that should be as far as practicable free from any material that was liable to break up into dust or mud. The meeting was attended by a number of engineers and others connected with tramways. The usual ballot for members and associates took place at the close of the meeting.

AMERICAN SOCIETY OF CIVIL ENGINEERS.—As we go to press preparations are in progress for the annual convention of the Society at Louisville, on 21st and 22d of May.

The following papers are in readiness for the meeting:—

Light-draft Iron Steamers on Western Rivers—Theodore Allen, M. E., New York.

Beams—Gen. J. G. Barnard, New York.

Operations of the Teredo in Southern Waters—G. W. R. Bayley, C. E., New Orleans, La.

Water Power of the Falls of the Ohio—Morris S. Belknap, C. E., Louisville, Ky.

Detroit River Tunnel—E. S. Chesbrough, C. E., Chicago, Ill.

Experiments upon the Resistance to Compression of Wrought Iron Struts—Thomas C. Clarke, C. E., Philadelphia, Pa.

Production, Traffic, and Transportation of Freight and Passengers—Martin Coryell, C. E., Wilksbarre, Pa.

Economy of Railroad Curvature—Wilson Crosby, C. E., Brooklyn, N. Y.

Planting Considered as an Element of Engineering Construction—John Y. Culyer, C. E., Brooklyn, N. Y.

Causes of the Formation of Bars at the Mouths of Rivers—Gen. Theodore G. Ellis, Hartford, Ct.

Levee Building on the Mississippi River—C. G. Forshey, C. E., New Orleans, La.

Foundations under Water—Gabriel Jordan, C. E., Montgomery, Ala.

Foundations of the New Capitol at Albany, New York—Hon. William J. McAlpine, Pittsfield, Mass.

Screw Pile Foundations—Gen. W. Sooy Smith, Maywood, Ill.

Tables of the Strength of Cast-Iron Columns—Edwin Thacher, C. E., Louisville, Ky.

Backwater in Rivers as Caused by Dams—Prof. De Volson Wood, Hoboken, N. J.

Other papers may be offered.

IRON AND STEEL NOTES.

DEPHOSPHORIZING IRON IN PUDDLING.—We understand that a patent has been applied for in this country for the process of Professor T. Scheerer, of Freiberg, which was briefly alluded to in our last report, and which consists in adding a mixture of equal quantities of chloride of calcium and common salt to the molten iron in the puddling furnace, and then rabbling it in; as, however, the patent is not yet completed, we cannot communicate the details of its claims. Accounts of recent trials made of the process in Germany speak favorably of it, and state that the expense is in greater part covered by the shortening of the operation and the diminishing of the loss of iron.

ROLLING IRON.—The memoir of Mr. Daelen on the construction of the grooves in rolls, to which the prize was awarded by the "Verein zur befoerderung des Gewerbfleisses in Preussen," has been translated into French, and will be found in the 3rd part (for May, 1872) of the "Revue Universelle des Mines," etc.

The system of rolling invented by M. H. Vigour, of Ardennes, in France, has been recently patented in England, and is described as certain improvements whereby iron bars, having both round and square parts or other different sections, shall necessarily be rolled of exactly equal diameter in both the round and square parts or other sections. These improvements consist in placing, immediately behind two horizontal cylinders grooved partly round and partly square, or other varied section, two vertical cylinders having exactly similar grooves, and in placing between the horizontal cylinders and the vertical cylinders a continuous guide, which takes the iron as it issues from the horizontal cylinders, and leads it into the vertical cylinders.

INFLUENCE OF MAGNETISM ON STEEL.—In October, an account of certain experimental investigations made by MM. Trève and Chedeville, to ascertain whether the influence of magnetism changes in any way the internal structure and powers of resistance of cast steel, was communicated to the Academy of Sciences at Paris. In these experiments two cylindrical moulds precisely similar one to another were filled with molten cast steel, one of which was, during the entire period of the cooling of the steel, surrounded by a coil made by Ruhmkorf, through which the current from a 12-element Bunsen's galvanic battery was passed, whilst the other was allowed to cool as usual. At the expiration of ten hours the two steel cylinders were taken out, and each broken in several fragments in order to examine their internal structure, when it was found that the grain of the metal differed considerably in appearance in the two castings, the grain being visibly finer in that subjected to mag-

netic influence during cooling, which was found to be the case also in three instances in which this experiment was repeated. Comparative experiments were then made by M. Ch. deville as to the resisting power of the two steel castings to extension and compression, the results of which indicated that the magnetized steel offered in every instance less resistance than the other.

TUNGSTEN STEEL.—Chemical analyses of Mushet's so-called "special" steel, which is remarkable for its hardness and strength, have been made by a chemist in Hanover named Heeren, who has published his results, and finds it to be merely tungsten steel containing 8.73 per cent. of tungsten along with 1.73 per cent. of manganese. This class of steel is manufactured in Germany at the works of Messrs. Wund & Co., at Buckaw, near Magdeburg, in Prussia, and in Hanover at Uslar on Solling, and the magnets used by Messrs. Siemens's telegraphic works in Berlin are also made at Moabit of this steel. Its qualities are very different from those of ordinary steel, as although when annealed it is so hard as to resist the best files, it becomes soft when chilled, and presents an exterior full of cracks, for which reasons it must not be hardened. At a red heat it is malleable and easily worked, but all tools made of it must be brought into shape by the hammer at once, and finished if necessary under the grindstone, as the file will not touch it afterwards. Tools of tungsten steel in use for planing and other machines at the Engine Works of Messrs. Knoevenagel, in Hanover, are reported to stand longer than those made of the best Sheffield cast steel.

In "Kicks techn. Bl. Heft 2," p. 122, 1872, it is stated that a steel analyzed by Messrs. Mueller and Kick, which contained 8.777 per cent. tungsten, 2.527 manganese, 0.759 silicon, 0.009 phosphorus, 80.01 sulphur, and 0.405 titanium, was not found to be of good quality.

A species of steel invented by Mr. H. A. Levallois, of Paris, has lately been patented in England (August 10, 1872, No. 2,389), which is stated to be an alloy containing tungsten and nickel in various proportions, and claimed to be less liable to oxidize or rust than ordinary steel.

THEORY OF THE BESSEMER PROCESS.—In opposition to the deductions which Kupelweiser and Snelus have drawn from their chemical analyses, Kessler finds that in the Bessemer process of steel-making, the entire amount of carbon present (owing to the oxidation of the other substances being, in the commencement of the "blow," more energetic increases relatively. as in puddling, and that the carbon first begins to oxidize after the major part of the silicon has disappeared. The amount of phosphorus in the steel decreases in the middle stage of the process, but increases both in the commencement of the "blow"—owing to the relative greater oxidation of the other substances—as well as at the end, when it is, in part at least, taken up again from the slag. Sulphur decreases rapidly at first, but then increases in the middle stage, up to the addition of the spiegeleisen, for the reason that a portion of it, which in the first stage went into the slag in the form of metallic sulphides, was afterwards again taken up by the iron. So long as the manganese is being oxidized and removed from the iron, the percentage of sulphur in the iron diminishes; but as soon as the iron is free from manganese, it again takes up a portion of the sulphur contained in the slag. When the spiegeleisen is added, and the "blow" recommenced, the sulphur again diminishes; and if the first slag (which is sulphurous) could be removed, then it would be possible to use brands of iron which are known to contain sulphur for making Bessemer steel.

AMOUNT OF MANGANESE IN DIFFERENT STEELS.—Kessler, in Dingler's "Polytic. Journal," vol. 205, p. 43, gives the results of the determination of the quantity of manganese in the following varieties of steel:—

Krupp's crucible cast steel, Essen	0.437 to 0.438 p cent.
Bochum cast steel	0.312 to 0.317 "
Hasper steel	0.327 to 0.322 "
Hoerder steel	0.167 to 0.170 "
Manganese steel of Ludvig, in Berlin	0.303 with 0.31 silicon.
Fine pianoforte wire	0.035 "

ESTIMATION OF MANGANESE IN IRON AND STEEL.—Kessler has investigated the separation of iron from manganese effected by the use of acetate of sodium and boiling, and finds the process to be defective in proportion to the quantity of acetate of sodium employed. Direct experiments gave the following numbers when 300 cubic centm. of liquid was used along with 15 grammes of acetate of sodium, without any free acetic acid:—

Actual percentage of manganese present	1.00	3.00	7.00	13.00
Loss of manganese in percentage	0.21	0.60	0.87	1.06

If, however, the solution of the iron be treated as follows, 1 gramme of acetate of sodium is sufficient to precipitate completely 1.1 gramme of iron from 500 cubic centm. of solution; and this precipitate carries down with it only from 0.02 to 0.05 per cent. of manganese, even if the iron solution contain as much as 13 per cent. of manganese so that in such case the error is so small that it may be overlooked. The hydrochloric solution of chloride of iron is neutralized with carbonate of sodium until a permanent precipitate is formed, and then hydrochloric acid is added cautiously until the precipitate is just redissolved. The liquor then contains fourteen-fifteenths of the iron dissolved as hydrate in the chloride of iron solution, this hydrate not being separated by boiling. The acetate is then added, and the whole boiled a few minutes.

NEW PATENT BLAST FURNACE AT SUMMERLEE.—This week a new patent blast furnace was put in operation at Summerlee by the Messrs. Neilson. Since the era of the hot-blast, originated by the uncle of the senior partner of the firm at Summerlee, there has not been a more bold contrivance introduced into the iron trade of Scotland than that inaugurated yesterdy. The furnace is totally different from the flue system adopted by Mr. Ferrie at Calderbank, Mr. Pultney, the manager at Summerlee, being of opinion that the flues

at the top of the furnace may with advantage be dispensed with. The whole secret of the present operation depends upon the elevation of the furnace, and the proper distribution of the gas generator. The chief deviation from the plan previously adopted is that the furnace has been elevated from 50 ft. to fully 70 ft., with a gradually-sloping furnace from 16½ ft. at the boshes to 12 ft. at the top, the raw material being filled upon equal layers, and the blast modulated according to circumstances. The blast was turned on by Miss Neilson, amid great applause. Lunch was thereafter served up to a select company, and "Success to the New Furnace" was proposed by James Neilson, Esq., of Mossend. Mr. Neilson, of Summerlee, responded.—*Engineer.*

A New Fuel for Locomotives.—The Russian Steamship and Railway Company annnounces that it has found the use of naphtha, for steam-generation with locomotives, very advantageous. The material employed by the company is the crude oil from the Caucasian and Volga regions, and, compared by weight, the amount consumed was about one-half that of coal. The arrangement for burning naphtha is stated to be of such a nature that no difficulty will be experienced in substituting one for coal consumption in place of it, should it be found desirable so to do.

The Iron Outlook Abroad.—There was continued firmness in the British iron trade on February 8th, the date of our last advices by mail. In South Staffordshire there is a general advance in the price of finished iron. Common bars are quoted at £12 to £12 10s., and marked bars at £13 to £13 10s.; plates, £16 to £17. Pig iron is firm, but few makers are open to accept orders. In North Staffordshire much inconvenience is experienced on account of the short supply of coal. In the Cleveland district pig iron No. 3 is quoted at 120s. All other numbers are dear in proportion, No. 1 being scarce at 127s. 6d. Rails are quoted at £12 10s. per ton. Purchasers hesitate to buy at this price. The difficulty of getting coal and coke is becoming greater every day. In South Wales there seems to be no nearer approach to an agreement between the masters and the men. But few rails are made. In Scotland the stocks of pig iron in store have been reduced since Christmas about 14,000 tons. The supply is not equal to the demand. The high price of pig iron is affecting injuriously the makers of manufactured iron, who have to push about for orders to keep their machinery going. Prices, however, were somewhat easier than the week before, ranging from 132s. 6d. to 135s. In Belgium and France prices remain firm, and in both countries the production of iron daily displays a continual tendency to increase.—*Bulletin of the American Iron and Steel Association.*

RAILWAY NOTES.

Chapin's Electro-Magnetic Continuous Railway Break.—The apparatus consists mainly of a battery and keyboard, conductors and magnetic clutch, and the mechanical arrangement of gear for applying the blocks to the wheels. The battery used is that known as Highton's, consisting of 16 cells, and is placed in each guard's van. Conductors pass through the train, the couplings of which are very ingenious and simple, being so arranged, that should the train part, the circuit would be instantly reformed, and the break as perfect as before, each part of the train having its own break apparatus complete. A magnetic clutch is placed under each carriage, which is constructed as follows:—A horizontal shaft having a friction roller loose on it in contact with one of the carriage axles, is supported at one end by a fixed bracket, and at the other by a sling link; adjoining this link and on the shaft is a fusee, to which is attached a chain on the shaft, and having a wrought-iron friction plate in contact with an armature revolving with the friction-roller, is provided with a cast-iron disc, provided with two electro-magnets; play is allowed to the armature plate, so that it can approach to or recede from the friction plate. The main wires or conductors are connected to the magnets by means of two saddle pieces, spanning corresponding grooves in brass rings, fixed on a wooden collar pinned to the axle; this of course allows the shaft to revolve without disturbing the wires. Along the shaft, protected by coils of hemp, pass the two wires from the magnets to the saddle pieces, so that the current of electricity passes from the battery, down one saddle piece, through the magnets, and up the other saddle piece, then to the next clutch, and so on till the circuit is complete. Under each carriage and fixed to suitable framing are two levers, one horizontal, having its fulcrum in the centre of the carriage framing, and the other, vertical; to one end of the latter is attached a chain, connected to the fuse on the clutch shaft while another chain is connected to it (the vertical lever) nearer its fulcrum, the other end of which then is attached to the end of the horizontal lever, to which are also connected tension rods extending to the break block cross bars. The blocks are of wood, hung in the usual manner. The application of the break is effected by simply moving the key in the guard's van. The shaft thus winds up the chain to remove the breaks; the current is reversed, and the armature is released, and the blocks are drawn off by means of springs fastened to the head-stock of the carriage. A local battery is fixed in each carriage, the conductors of which have in their circuit the magnetic clutch and a key-board fixed on the roof of each carriage. The circuit is kept open by means of a cord passing through the keys to the vans at either end of the train, where its extremity is loaded with a weight to keep it tight. On the train parting, the cord is broken, and the keys by means of small springs instantly complete their circuits and apply the breaks.

The project is being reviewed of building a railroad on the east side of the Monongahela river, its northern and southern termini being Brinton's station, on the Pennsylvania railroad, and Brownsville, on the Monongahela, there to connect with the Pittsburgh, Virginia and Charleston railroad, now in course of construction. The contemplated line crosses the Youghiogheny at McKeesport. This would be an important feeder for the Pennsylvania railroad, and is a shorter route than that through the Miller's Hill tunnel now being excavated at Port Perry.—*American Manufacturer.*

THE subjoined table shows the different classes and quantity of freight through and local) transported by the Union Pacific railroad during 1872:

Coffee, lbs.	2,039,539
Tea "	974,019
Silk "	12,291,209
Wine, casks.	8,364
Ore, tons.	11,862
Bullion, tons	7,029
Fruit, lbs.	2,463,445
Cotton, lbs.	537,692
Iron products, tons	26,966,051
Lumber, ft.	13,614,405
Timber, "	745,261
Wood, cords.	6,589
Coal, tons.	137,741
Hay, "	4,658
Grain, bushels.	1,309,203
Potatoes, bushels.	81,479
Live stock, head.	55,125
Hog products, lbs.	17,001,069
Beef, bbls.	82
Beef, dressed, lbs.	737,903
Merchandise, tons.	80,123

The total tonnage for the year is divided as follows:

Through.	161,157,266
Local.	596,142,817
Total.	757,300,143

—*American Manufacturer.*

AT a railway meeting recently held at Huntsville, Alabama a project was endorsed to construct a narrow-gauge road from that place northwest *via* Pulaski and Johnsonville, Tenn., to connect with the Cairo and St. Louis Railway; also one south to Tuscaloosa through the rich iron and coal fields of northern Alabama; and a railway connection southeast *via* Guntersville to Opelika, to connect the States of Alabama, Georgia and Florida with the short-line to the Atlantic. The Ohio, Tennessee and Warrior River railroad, by its route from Huntsville northwest toward Cairo, Ill., and its line south to the Tennessee river,—thence diverging south from Guntersville to Tuscaloosa,—will secure this subject, to which the meeting gave hearty approval and pledged earnest co operation to the enterprise.—*American Manufacturer.*

ENGINEERING STRUCTURES.

TRAVELLING CRANES.—At a Meeting of the Manchester Scientific and Mechanical Society on Wednesday a paper on the above subject by Mr. Theodore Gross was read. After describing the improvements which had been carried out in the construction of cranes, Mr. Gross proceeded to give details of a new crane invented by himself. By this crane a new principle is introduced, of placing a balance weight at one end of the lever, which acts in conjunction with the lifting of the load, instead of the usual fixed weights on the plate at the centre of the crane. By this invention it is claimed that greater stability and safety are secured, with freer action than a lighter crane, which are the most important points in all travelling machinery of this description. During the discussion which followed, the only objection raised was that the new crane involved waste of power in having to lift the movable balance weight, but it was pointed out that the great inconvenience and labor of adjusting by hand the usual balance weights will be saved.

THE SEVERN TUNNEL.—The borings which have been undertaken in order to test the practicability of carrying a tunnel under the Severn are making rapid progress, the shaft being already driven about 40 yards on the Monmouthshire side. The engineers, it is stated, entertain no doubt of the difficulties connected with such a scheme being surmounted, and it is then said that in a period of about five years the Severn Tunnel will be completed. If such anticipations prove correct, South Wales will have the advantage of more direct communication with the metropolis, and a great saving in the distance by rail to the West and South of England.

ORDNANCE AND NAVAL.

THE COMPOSITE GUNBOATS.—A recent number of a contemporary contained an article on the composite gunboats of the navy, in which the writer betrays such ignorance of his subject, that we feel compelled, in the interests of truth, to set him right.

We are told, for instance, that these gunboats are useless; that they have no special merits, and many defects; that their light draught has been purchased at the cost of steadiness, and much more to the same effect; for not one of which statements, we venture to say, could the writer, if put to the test, produce an authority. A reference to the "Navy List" shows that of five of these little boats that are in commission (not *three* as the writer of the article erroneously states three are employed on the West Coast of Africa, one in China, and one at home as tender to the Audacious. It must be remembered that the English navy, in times of peace at all events, has come to be looked upon as a species of police of the seas. In the performance of these duties, it is necessary for us to have vessels, in the least civilized parts of the world, on every sea and almost on every river, ready to crush in an instant any attempt at piracy or slave trading. For this purpose various descriptions of vessels are required, and among them gunboats, like those to which we refer, of shallow draught, and sufficiently well armed to be able to cope successfully with any ordinary antagonist. Granting the necessity for these shallow-draught vessels, which, indeed, cannot be disputed, we altogether fail to see any objection to their being built on the composite principle, a mode of construction that enables them to be coppered, no small advantage in the waters of the African coast and in the Eastern seas.

Another point, to which exception is taken, is that these gunboats are furnished with three masts, which, we are informed, will probably be found a great deal too much for the vessels in anything like bad weather, apparently ignoring the fact that it is in the power of the officer in command to decrease the amount of sail carried, according as the safety of his vessel may require. At least as much may safely be predicted of every ship with full sail-power.

It also appears, at least according to the writer,

that the gunboats are jeopardized by their not having a keel (we afterwards discover that a false keel is meant), and by their being fitted with bilge-pieces, 10½ in. in depth, which, Mr. Froude will probably be surprised to learn, "are very generally admitted to be a very imperfect substitute for a false keel in preventing rocking" *rolling*, we presume the writer intended to say). Towards the end of the article, we discover what has caused the writer to take such an intense dislike to these composite gunboats, viz., that they are inferior to the Staunch class, with what he oddly terms their adaptation of the Moncrieff gun-carriage. Now, we have no wish to disparage in any way the Staunch and her sister vessels. Their design displays much ingenuity, and Mr. Rendell deserves great credit for his idea; but we must protest against the very considerable amount of nonsense that is talked about them by many writers in the press. It is simply ridiculous to pretend that a fleet of these boats would keep a fleet of ironclads at bay, or that they would suffice by themselves for the defence of Liverpool or any of our other great commercial ports. No doubt they possess certain good qualities; but does anyone else, or are we desired to seriously believe that the gunboats of the Staunch class are fitted to make the voyages and perform the services that are now being made and performed by the composite gunboats? If this is the view of the writer in question, we can only say that he must be gifted with a more vivid imagination than any of the sensation novel writers of the day.—*Iron.*

THE TOW BOAT AMERICA.—This famous steamer, well known in all the Atlantic ports of the United States, arrived at New York on the 14th inst., and towed the Portuguese ship Marianna VII. to Philadelphia—one of the Guimaraes line of packets.

The America was built at Philadelphia by John W. Lynn, for Capt. Henry Virden, Stephen and J. M. Flanagan and Henry Winsor, and hails from that port. Her hull is of oak, 135 ft. in length, 28 ft. beam and 12 ft. 4 in. depth of hold. Her engine is of the ordinary type of inverted cylinder direct acting, 40 in. in diameter and 36 in. stroke. The screw is 10 ft. in diameter and her average speed, 12 knots. Her work has extended along the entire Atlantic Coast of the United States and among the West India Islands. Among her noteworthy performances may be mentioned the towing of the ex rebel ram Lady Davis from Norfolk to Philadelphia; she afterwards towed the same craft from Philadelphia to Boston, making the run of 380 miles from Cape Henlopen to Boston in 62 hours. The America recently towed the ship Great Admiral from Boston to New York in 36 hours, a distance of 302 miles.

She has towed vessels from Nassau to New Orleans and the ships Peerless and Sonora, from Boston to New York. The officers of the America are: Captain, Henry Virden; Mate, Peter Chambers; Chief Engineer, Edward Messick.

VIENNA EXPOSITION.—A rare opportunity is afforded to such of our citizens as desire it, of securing first-class passage by the fine steamer Vaderland, to sail from this port on the 1st of May for Antwerp. By this line travellers can reach Vienna directly by rail in shorter time, and with greater saving in distance and expense, than by any other route. There are no steamers afloat whose construction guarantees greater security to travellers than the steamers of the "Red-Star Line." They are built of iron, of great strength, with double bottoms and double side, extending up to the lower deck, and are divided into permanent water-tight compartments with double bulkheads fore and aft. They are commanded by efficient and experienced officers, and every department of the service has been organized so as to command the confidence of the travelling public.

The Vaderland made her last passage from Antwerp to the Capes of the Delaware in thirteen days. The state rooms of these steamers are large and well ventilated. They are placed amidships, where there is the least motion, and open directly into the saloon, which insures greater comfort to passengers.

BOOK NOTICES.

A TREATISE ON THE STRENGTH OF BRIDGES AND ROOFS, WITH PRACTICAL APPLICATIONS AND EXAMPLES, FOR THE USE OF ENGINEERS AND STUDENTS. By SAMUEL H. SHREVE, A. M., Civ. Eng. D. Van Nostrand: New York, 1873.

Those readers who have kept themselves *au courant* of contemporaneous engineering literature, have doubtless noticed that from time to time the pages of "Van Nostrand's Eclectic Engineering Magazine," have contained very able papers on the subject of bridge calculations from the pen of Mr. S. H. Shreve, C. E. We have now before us a handsome octavo volume, issuing from the same press as the above-named magazine, in which Mr. Shreve presents a thorough recast of his previous articles, with a much more systematic and extended development of the subject than was possible in the papers referred to.

In the present volume, Mr. Shreve attempts the algebraic solution of all problems relating to the stresses in the various parts of every description of trussed girder now in use. The method by which these problems are treated is more purely analytical than that adopted by any other writer, as far as we know, and we may at once state that by the dexterity with which Mr. Shreve handles some of the very complicated problems which his subject offers, he has vindicated his right to a position among the most eminent interpreters of applied mechanics.

The first two chapters of the work are devoted to establishing expressions for the maximum horizontal and vertical strains in straight trusses with simple bracing. These expressions, established for this class of trusses, form the basis from which those applicable to all other forms are more or less directly deduced. In establishing these formulas, Mr. Shreve pursues a method which precisely inverts the order adopted by most of our best writers. We are all familiar with the method, developed in so masterly a manner by Mr. Stoney, by which the strains in the flanges or chords of a straight truss are deduced from those in the inclined members of the web. Mr. Shreve, on the contrary, ascertains by statical moments the strain in the chords, and thence deduces those in

the ties and braces. It will be at once perceived how valuable either of these methods is, as a check upon the other. They form a complete system of reversion, and the basis of each is ascertained by a process entirely independent of the other. To Mr. Shreve belongs the credit of fully establishing this contrary method of calculation, which to make the contrast complete, he does by an analytical process quite distinct from the synthetical reasoning of Stoney.

As an example of the manner in which Mr. Shreve applies his analysis, we would call attention to the formula on page 31, for determining the point of maximum horizontal and vertical strains occasioned by a partial load, and especially to the investigation, from page 44 to the end of Chapter II., by which the effect of the half panel weight beyond the loaded segment of a partially loaded simple truss is incorporated into the general formula for the maximum vertical strain.

Chapters III. to VI. inclusive contain discussions of the principal straight trusses in use, and show the applicability of the general formulas to these cases.

Nothing can be more direct and practical than Mr. Shreve's method where applied to simple trusses. We cannot but think, however, that, as applied to the compound truss, it fails in simplicity when compared with the system by resolution of forces. As moments can only be taken at points where a vertical plane cuts no member giving a horizontal component, the method is not applicable to compound trusses considered as such. Compound trusses must therefore be prepared for calculation, by being reduced to the simple systems of which they are composed. Each simple system must then be calculated separately, and their strains added together to obtain the totals. By resolution of forces, a compound truss can be calculated as a whole, and with the same ease and simplicity as a simple truss. The method by moments, however, is worked out by Mr. Shreve with great skill, in these cases, and affords a valuable check upon the other method.

No mention is made in this volume of the form of compound truss in which the ties and braces of certain of the systems abut against the end post, and give rise to unsymmetrically placed permanent truss weights.

In Chapters VII. to IX. inclusive, problems of roofs and triangular trusses are solved, by modifications of the general formulas applied to parallel trusses. In subsequent chapters, bow string, lenticular and other forms of trusses are taken up, and solved by directly analytical calculation. These chapters perhaps show Mr. Shreve's abilities as an analyst more strikingly than any other portion of the book. The usual method of calculating these trusses is by the use of diagrams, but Mr. S. has successfully grappled with them by means of simple algebra and a very little conic sections.

En résumé of this hasty sketch, we would say, that in this volume Mr. Shreve has established an entirely new method of calculating bridge strains, which he has unswervingly and successfully applied to all systems of trussing. In special cases this method may not be the simplest, but it is consistent, ingenious, and affords the best possible check upon other systems of calculation. In developing it, Mr. S. has given evidence of great analytical skill, and a power of patient, conscientious investigation which deserves all praise. His volume will deservedly stand in the first rank of engineering literature.

INDIA AND INDIAN ENGINEERING. Three Lectures delivered at the Royal Engineer Institute, Chatham, in July, 1872, by JULIUS GEORGE MEDLEY, of the Thomason Civil Engineering College, Roorkee. (London: E. and F. N. Spon, 1873.

In this little work of 119 pages is to be found a condensed mass of information of a character that is not ordinarily accessible. Just as the Arctic and Antarctic seas, and the associated expeditions of exploration and discovery, have for long years been the school and origin for our most intrepid and skilful sailors, so has India, ever since the days of Robert Clive, been the training ground of all our most highly skilled officers both of the line and of the scientific services, especially the engineers. The great extent and natural resources of the country, the difficulties and diversities of its climatic and physical features, the vast scale of its rivers, mountains, and plains, and the peculiarities of its myriad population, with a small nucleus of Europeans—all these things have combined to magnify and alter the conditions of engineering enterprise, as compared with similar works at home. On all these points our lecturer has something interesting and instructive to say; but the special aim has been to illustrate the system of Public Works in India, and in particular the nature and objects of the Thomason Engineering College at Roorkee, founded about twenty-five years since, and now containing about 150 students. The practical subjects briefly treated are thus enumerated in the Syllabus prefixed to the lectures:—Building Materials: stone, brick, tiles, limes, timber, iron, wages and rates, weights and measures, absence of plant, water-raising machines, carts; Foundations: well-cylinders, Indian rivers; Barracks: difficulties of ventilating and cooling, private houses, churches, other buildings; Bridges: temporary, permanent, waterway; Roads: metalling, hill-roads; Railways: various lines, permanent-way, traffic arrangements; Irrigation Works: their importance, the Ganges Canal, crops and soils, design of canals, the head, velocity of stream, falls and rapids, drainage works, irrigation details, Madras weirs, tanks; River Works: inundations, spurs; Indian Survey Department: the great trigonometrical survey, topographical survey, revenue survey. The Indian Survey Service, it is well known, has turned out some of the most accomplished and laborious known to the nation—such as Lambton, Everest, etc., and last, not least, the gallant Major Basevi, who recently died, in harness, a solitary observer in the plains of Thibet. With such materials, and in skilled hands, it is not to be wondered at that the result is a valuable synopsis and a pleasant study.

PRINCIPLES OF ANIMAL MECHANICS. By Rev. SAMUEL HAUGHTON, F. R. S. London: Longmans, Green & Co. For sale by Van Nostrand.

We have only the opportunity just now to give such information respecting this new work as will be afforded by the statement that the following topics are treated at considerable length and with many illustrations.

Dynamical work done by Muscles—The absolute

force of Muscles—The mechanical work done by the human heart—Classification of Muscles and their modes of action—Application of general laws of Muscular action.

COURS DE PHYSIQUE.—Par CH. BRISSE et CH. ANDRÉ. Paris: Dunod. For sale by D. Van Nostrand.

This is a work of 600 pages—treats of all ordinary topics of general physics except heat. It is designed for more advanced students than Ganot's work, though it is less rigorous in method than the larger work of Jamin. It is exceptionally full on the subjects of Electricity and Magnetism. Illustrations to the number of 470 are interspersed in the text.

PRINCIPES DE LA CONSTRUCTION DES ORGANES DES MACHINES. Par F. REDTENBACHER. Paris: J. Baudry. For sale by D. Van Nostrand.

This fine work is a treatise upon just so much of mechanics as applies to machinery. The book is in no sense of a popular character, as it brings the higher mathematics to the aid of investigations whose aim is the correct proportioning of machines.

The separate sections bear titles as follows:

1*st*. Elasticité et resistance des materiaux.
2*d*. Construction des pieces de machines.
3*d*. Calcul des résistances passives.
4*th*. Des engrenages.
5*th*. Des mecanismes de mouvement.
6*th*. Machines mues par la force de l'homme.

A fine atlas of plates accompanies the text.

THE TELEGRAPHIC JOURNAL AND ELECTRICAL REVIEW. Edited by Rev. WM. HIGGS, M.A., LL.D. London: Henry Gillman.

To readers who desire to keep up with the advance of Electrical Science, the "Telegraphic Journal" is a necessity. The practical applications of electricity to telegraphy are, of course, accorded the first place in the "Journal," but the latest investigations in the departments of static and dynamic electricity are afforded to its readers. The illustrations are abundant and the typography good.

STOCK AND INTEREST TABLES. By JOHN N. STOCKWELL, M. A. New York, 1873: D. Van Nostrand.

This work comprises tables showing matured and present value of bonds, stocks and other securities, together with annuities, compound and simple interest, etc., etc.

The tables are in antique type on a large tinted quarto page.

EQUILIBRE STABLE DES CHARPENTES EN FER, BOIS ET FONTE. Par EUG. CORDIER. Paris: Dunod. For sale by Van Nostrand.

This large quarto contains formulas and tabulated values for resistance of various materials in any form in which they are likely to be employed.

The excellent plan has been adopted of printing in large type and with liberal spaces.

A TOUR IN THE UNITED STATES AND CANADA. By JULIUS GEORGE MEDLEY. London: Henry S. King & Co.

Most Americans are interested in knowing what intelligent English travellers think about the United States. The writer of this little book chats in a very candid and off-hand manner about a trip of two or three months through the States. The schools, journals, engineering works, societies of all kinds are all measured by the author's standard, which is in the main a just one. It is a very readable book.

LES MACHINES. Par EMILE WITH, C. E. Paris: J. Baudry. For sale by D. Van Nostrand.

This is a work rather upon mechanism than mechanics, although the fundamental principles of the latter science are clearly given in the first chapters.

The elementary parts, of important classes of machines, together with the history and use of particular forms, occupies a large portion of the book.

The division in chapters is as follows:

1*st*. Principes de la Mecanique appliquée aux Machines.
3*d*. Organes des Machines.
3*d*. Machines de Precision.
4*th*. Machines a déplacer les Fardeaux.
5*th*. Machines de compression des solides et de percussion.
6*th*. Machines a élever les liquides.
7*th*. Machines a mouvoir les gaz.
8*th*. Machines d'exploitation des mines.
9*th*. Machines a enlever les terres.
10*th*. Machines a perforce et a abattre les roches.
11*th*. Machines outils.
12*th*. Machines motrices a forces naturelle.

Fine wood-cuts to the number of 288 are interspersed in the text.

DICTIONARY OF TERMS IN ARCHITECTURE, ENGINEERING, MINING, ETC. By JOHN WEALE. Fourth Edition. By ROBT. HUNT, F. R. S. London: Lockwood & Co. For sale by Van Nostrand.

The object of this work is explained fully by its title, and when we add that it is a neat 12mo volume of about 600 pages the scope of the work is also very nearly expressed.

The editor of this new edition seems to have faithfully performed the task of improving the former edition to satisfy the new demands of scientific progress.

MISCELLANEOUS.

THE oldest steamer in the world has been presented by her owners to the Glasgow Chamber of Commerce. The vessel is named the Industry, is 64 tons register, and was launched from the building yard of Messrs. John and William Fyfe, of Fairlie, on the Clyde, in 1814. She was the seventh steamer built on that river. Latterly she has lain sunk in the East India harbor at Greenock; but a few weeks ago she was floated and beached, to be caulked, thereafter to proceed to Glasgow, where she will be preserved as a memento of the early days of steam navigation.

PLATINUM.—The idea of platinum coinage continues to be a subject of discussion among the scientists of Europe. No other metal, not even gold or silver, possesses so many inherent qualities for such use. It would be proof against forgery on account of its high specific gravity; its scarcity

gives it an intrinsic value, and its indestructible nature admirably fits it for standing the wear of constant use. It has already been largely used for medals in France, and successful experiments have been made for converting it into coin. In Russia it was used for coin previous to 1845, when it was demonetized by imperial ukase. That step was taken at the time because the ready methods of working and refining the metal were not well understood, That objection is now, however, fully removed.

AUSTRIAN IMPORTS OF METALS.—In no country of Europe have commerce in general, and metal industry and manufacture in particular, made such rapid progress as in Austria during the last few years. The imports of iron continue to increase. In the months from January to November, 1872, inclusive, the import exceeded that of the whole preceding year by 464,642 centners. In preceding years the imports were, in 1868, 2,500-000; in '69, 3,000,000; and in '70, 3,200,000. The importations of wholly and partially manufactured iron, also, in 1871, and from January to November, 1872, were in the following proportions:—

	1871.	Jan.-Nov., 1872.
Iron, various	409,149	752,133 centners.
" plates and sheets	171,573	175,964 "
" castings	222,922	269,879 "
" wire	49,735	70,091 "

TRACING PAPER.—A convenient method for rendering ordinary drawing paper transparent for the purpose of making tracings, and of removing its transparency so as to restore its former appearance when the drawing is completed, has been invented by C. Puscher. It consists in dissolving a given quantity of castor-oil, in one, two, or three volumes of absolute alcohol, according to the thickness of the paper, and applying it by means of a sponge. The alcohol evaporates in a few minutes and the tracing paper is dry and ready for immediate use. The drawing or tracing can be made either with lead pencil or india-ink, and the oil removed from the paper by immersing it in absolute alcohol, thus restoring its original opacity. The alcohol employed in removing the oil is, of course, preserved for diluting the oil used in preparing the next sheet.

A CHINESE mandarin, named Yung Wing, has been visiting Philadelphia, having recently succeeded in obtaining the approval by the Imperial Government of a plan he has conceived for the introduction of iron manufactories into China, and the object of his visit to Philadelphia was to inquire into American methods and processes. China is rich in deposits of iron ore, and both anthracite and bituminous coal, but the Imperial Government has thus far not permitted their development. Nor is there a single railroad in China. Young Wing entertains strong hopes that an era of industrial development is about to dawn upon his country.

WHITE METAL ALLOYS FOR MACHINERY.—An alloy of 90 per cent. tin, 8 per cent. antimony, and 2 per cent. copper, has been found excellent for crank and connecting-rod bearings on the Moscow and Nishni Railroad. On the Kursh Charcow-Asow Railroad an alloy of 78.5 per cent. tin, 11.5 antimony, and 10 copper, is considered very superior for pivots of all kinds, slide valves, eccentrics, stuffing-boxes, etc. The Swiss Nordöstbahn Company, in ordering locomotives recently, required the following preparation as a composition for axle journals: 10 parts of antinomy added to 10 parts of melted copper, with 80 parts of tin added, and the alloy run into bars, to be remelted for use.

ACCORDING to Schutzleder, of Gosling, watchmakers temper the points of drills, etc., so that they can be used upon steel tempered in the ordinary way, by heating them to a white heat, and inserting them into hard sealing wax, allowing them to remain but a second, then pushing them into another part of the wax, and again quickly withdrawing, to repeat the operation in a fresh spot, until they are too cool to penetrate the wax. The tool is to be moistened with turpentine when used.

TO open a water route from the St. Lawrence river to New York city, as is proposed, would necessitate a canal 29½ miles long between the St. Lawrence and Lake Champlain, costing $3,500,-000, and the improvement of the upper Hudson, costing $6,500,000, according to the estimates of Mr. W. J. McAlpine.

ESTIMATION OF SULPHUR IN IRON AND STEEL. — Mr. T. T. Morrell has recently made known a new method of estimating the quantity of sulphur impurity in iron.

The more common method of estimating sulphur in iron and steel consists in acting on the metal with sulphuric or hydrochloric acid, and precipitating some metallic sulphide by the evolved sulphuretted hydrogen. It would be a desideratum, in point of time, if this sulphide could be directly weighed.

By passing the evolved gases through an ammoniacal solution of cadmium oxide (or a solution of sulphate to which an excess of ammonia has been added), a precipitate of cadmium sulphate is obtained which can be at once collected upon a small filter, dried at 212 deg F. and weighed. The phosphuretted hydrogen, evolved in the solution of the metal together with the sulphuretted hydrogen, causes no precipitate in the solution. The presence of ammoniacal salts would also prevent any precipitation of carbonate of cadmium by the traces of carbonic acid in the air drawn through the apparatus by the aspirator after the metal is dissolved. However, the aspirated air could easily be passed through potash solution, to remove its carbonic acid. To prevent the precipitation of oxide of cadmium on the filter, the precipitate should be washed with distilled water containing diminishing quantities of ammonia. If, in very accurate estimations, it is necessary to estimate the minute quantity of sulphur left in the solution and residue of the metal, this can be done as usual and added to that found as above.

Five test analyses of a piece of Bessemer steel known to contain above .13 per cent. sulphur gave as follows:—

1st	.124 per cent.
2d	.124 " "
3d	.137 " "
4th	.125 " "
5th	.124 " "